FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

DEGREE PROGRAMME IN ELECTRONICS AND COMMUNICATIONS ENGINEERING

MASTER'S THESIS

MOODFOAM: AN ATMOSPHERIC EVALUATION OF MULTI-SPACES

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ABSTRACT

Understanding spatial experience is a multi-faceted problem which requires using tools from various fields. Spaces are rarely evaluated after they are built, and the spaces might not be used the way they were intended. This can lead to a lacking knowledge on how the spaces work or how they could be improved. This thesis aims to tackle this challenge by developing a methodology to gather data from a multi-space. To achieve this, a MoodFoam web application was developed for user surveys, and environmental sensor data was gathered from Tellus, a multi-space in the University of Oulu. The theoretical background of this thesis utilizes understanding from the fields of architecture, organization theory, philosophy, and psychology.

The subjective and contextual user data and the objective sensor data was gathered successfully during the study's two-week data gathering period. The data was analyzed and visualized with statistical programming language R to highlight various aspects of the spatial experience in Tellus. As a result, the methodology was able to produce subjective data with a time-space information allowing for a broader understanding of the multi-space and its users. The results suggest that even close-by spaces can have different atmospheres. Furthermore, the results found differences in the subjective experiences in the researched spaces, in terms of smell, temperature, and sound. The presented methodology can be further used in various contexts to improve its explicative capabilities.

Key words: spatial experience, Internet of Things, Human-Computer Interaction.

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TIIVISTELMÄ

Tilakokemuksen ymmärtäminen on monitahoinen ongelma, joka vaatii eri alojen menetelmien hyödyntämistä. Tiloja arvioidaan harvoin niiden rakentamisen jälkeen, eikä niitä välttämättä käytetä niille tarkoitetulla tavalla. Tämä voi johtaa puutteelliseen ymmärrykseen tilojen toiminnasta tai siitä, miten niitä voisi kehittää. Tämä diplomityö pyrkii ratkaisemaan ongelman kehittämällä metodologia monitilan datankeruuseen. Tätä varten kehitettiin MoodFoam-internetsovellus käyttäjäkyselyille ja sensoridataa kerättiin Telluksesta, monitilasta Oulun yliopistolla. Diplomityön teoreettinen tausta hyödyntää arkkitehtuurin, organisaatioteorian, filosofian ja psykologian tarjoamaa ymmärrystä.

Subjektiivinen ja kontekstuaalinen käyttäjädata sekä objektiivinen sensoridata kerättiin onnistuneesti diplomityön kahden viikon datankeruun aikajaksolta. Data analysoitiin ja visualisoitiin tilastollisella R-ohjelmointikielellä Telluksen moninaisten tilakokemusten korostamiseksi. Diplomityön tuloksena metodologia onnistui tuottamaan subjektiivista aika–paikka-tietoa mahdollistaen laajemman ymmärryksen monitiloista ja sen käyttäjistä. Tulokset viittaavat siihen, että lähekkäisilläkin tiloilla voi olla oma ilmapiiri. Lisäksi tuloksista löytyi eroja tutkittujen tilojen subjektiivisissa kokemuksissa hajun, lämpötilan ja äänen suhteen. Esiteltyä metodologiaa voidaan edelleen hyödyntää lukuisissa konteksteissa tehokkaamman kuvaavuuden kehittämiseksi.

Avainsanat: tilakokemus, esineiden Internet, ihminen–tietokone-vuorovaikutus.

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FOREWORD

The aim of this thesis is to study the spatial experience in the multi-space context of Tellus in the University of Oulu. The study was conducted in the winter and spring of 2020. The thesis was graciously supported by Suomen Rakennustietosäätiö RTS and Tellus, to whom I am the most grateful.

I would like to thank my supervisor Jari Hannu for allowing such a multi-disciplinary work to be done as well as for his effective guidance and influential optimism. Also, I would like to thank Simo Hosio for his expertise in HCI, his dedication to finding new in the cross-section of sciences, and for seeing the potential in the thesis by employing me to the Center for Ubiquitous Computing. Furthermore, I'm thankful for Aulikki Herneoja and Piia Markkanen from the Oulu School of Architecture for their valuable perspective, willingness for multi-disciplinary assistance, and finding time in their schedule. I would also like to thank Essi Ranta for her patience and precision in proofreading this thesis.

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Oulu, April 17, 2020

Ville Paananen

LIST OF ABBREVIATIONS

API	Application Programming Interface
HTTP	Hypertext Transfer Protocol
JSON	JavaScript Object Notation
MQTT	MQ Telemetry Transport
REST	Representational State Transfer

1 INTRODUCTION

This thesis presents a methodology to evaluate the spatial experience of an architectural space. The methodology combines environmental sensor technology, mobile user surveys, and data analyzation techniques to gain insight on the atmospheric qualities of spaces. The thesis focuses on the multi-space area Tellus in the University of Oulu. The study uses theoretical background from a literature review by including relevant information from fields of architecture, organizational management, electrical engineering, human-computer interaction (HCI), phenomenology, psychology, and philosophy.

1.1 Motivation and Aims

Previous studies in the field of spatial experiences focus often on the theoretical aspects. The motivation for this thesis is to bridge the gap between the theoretical understanding of spaces, the user surveys of the HCI, and the sensor data gathering of electrical engineering. As such, the thesis aims to bring up an understanding which cannot be achieved through the methods of a single field.

The rise of the new sensor technologies and mobile surveys allow this type of research to be done. Also, a further understanding of the ever-evolving spaces for working and recovery is essential when the new paradigms are introduced. Multi-spaces, which allow for a great amount of flexibility, can also have their challenges in privacy and noise concerns. As such, the study brings up new research opportunities for understanding these spaces in a multi-faceted approach.

As a personal motivation, in the beginning of this study, the discourse on spaces seemed quite lacking and did not have descriptive depth. Talking about spatial experience felt separated from the actual space, and the relativist nature of experience was not reflected in the vocabulary either. The linguistic difficulty pushed the thesis forward to use a sort of language to describe the experience more sensibly.

The aim of this thesis is to develop a methodology to gather data on spatial experience. This is achieved through the use of contextual user surveys and sensor data. These are combined to visualize the various aspects of spatial experience, and the atmosphere of the space. Furthermore, the thesis aims to use a new theoretical perspective to explicate different phenomena of the space.

1.2 Related Work

Even though the research on spatial experience is focused on theoretical aspects, there are increasingly more practical studies. Markkanen et al. utilized experience sampling methods and Bluetooth-based indoor positioning to research knowledge workers’ usage of activity-based office [1]. The research used an intervention to elucidate the response to a changed work environment. Rachuri et al. developed a mobile sensing platform, Emotion Sense, to gather contextual and subjective data on emotions [2]. It was able to find correlation between emotion and location, using the mobile phone sensors. Sandstorm et al. utilized the Emotion Sense to study the correlation between location and emotion [3]. The study found that social situations are linked to a more positive mood. Also, it was suggested that personality affects how spaces are experienced. Research by Andreani et al used eye-tracking technologies, proximity sensors, EEG wearable devices, and mobile applications to form a technologically augmented understanding of built environments [4]. It presents a wide scope of methodologies, however the lack of results requires further testing to validate their usability.

1.3 Theoretical Background

“Would one of your cells, if it put itself to it, understand your body?” asks Lefebvre [5]. To understand the qualities of multi-spaces and their users, theoretical and conceptual tools are needed. The spatial experience as a subject has such vastness and depth which cannot be tackled with the approach of a single field or discipline. Nancy Tuana aptly stated on the dualisms of the social and the natural, nature and culture, and the real and the constructed: “it is the *interaction* between them that is the world that we know and are of” (italics in original) [6].

A natural starting point is the human: the body, the mind, the senses. Along with the human comes cultures, social ties, and history. The other half of the spatial experience contains the aspects of the space humans live in. The spaces we build around ourselves bring meaning and rhythm to our lives. Simultaneously, we are molded by the same places. The space can remind us of our connectedness or solitude, our roles or lack thereof, or it can emphasize our belonging or alienation.

Spatial experience is highly linked with atmospheres. The experiential qualities of atmospheres have been brought up often in the field of phenomenology. In architecture, authors like Juhani Pallasmaa, Gaston Bachelard, and Gernot Böhme all attribute atmospheres to be an essential and holistic part of the spatial experience.

The main influencing theory is from a German philosopher Peter Sloterdijk on social organizations and atmospheres [7]. His theory is centered around foams which are a structure that forms organizations. Each bubble of the foam is a self-contained unit which has their own internal goals and logic. The organization does not have a common goal. Each bubble imitates the ones surrounding it while maintaining its immunity. In this research, the atmospheric qualities of each sphere are evaluated with surveys and environmental sensors. This is in line with sociologist Christian Borch’s request for a practical application of foam theory to further the understanding of organizational life [8].

To extend the Sloterdijk’s foam theory, it is combined with the concept of porosity described by Nancy Tuana. Porosity as a concept allowed to talk about different kinds of relationships between entities. In this study, porosity can be physical, social, or cultural, and the management of porosity is attributed to the spatial experience.

Analyzing spaces requires more than just geometric viewpoints, which is why ideas like James Gibson’s affordances allowed me to see the space as a dense, layered, and relational. Factors like time, culture, and social norms influence also the experiential qualities of spaces.

1.4 Tellus

This thesis focuses on Tellus Linnanmaa in the University of Oulu, Finland. Tellus is a study space with several different areas for different kinds of activities. There are spaces which support relaxation, a café for socializing, and meeting rooms of different sizes. The main entrance to Tellus is located in the center of the university, as shown in the Figure 1. The Tellus doors open to Café Tellus, as shown in the Figure 2.

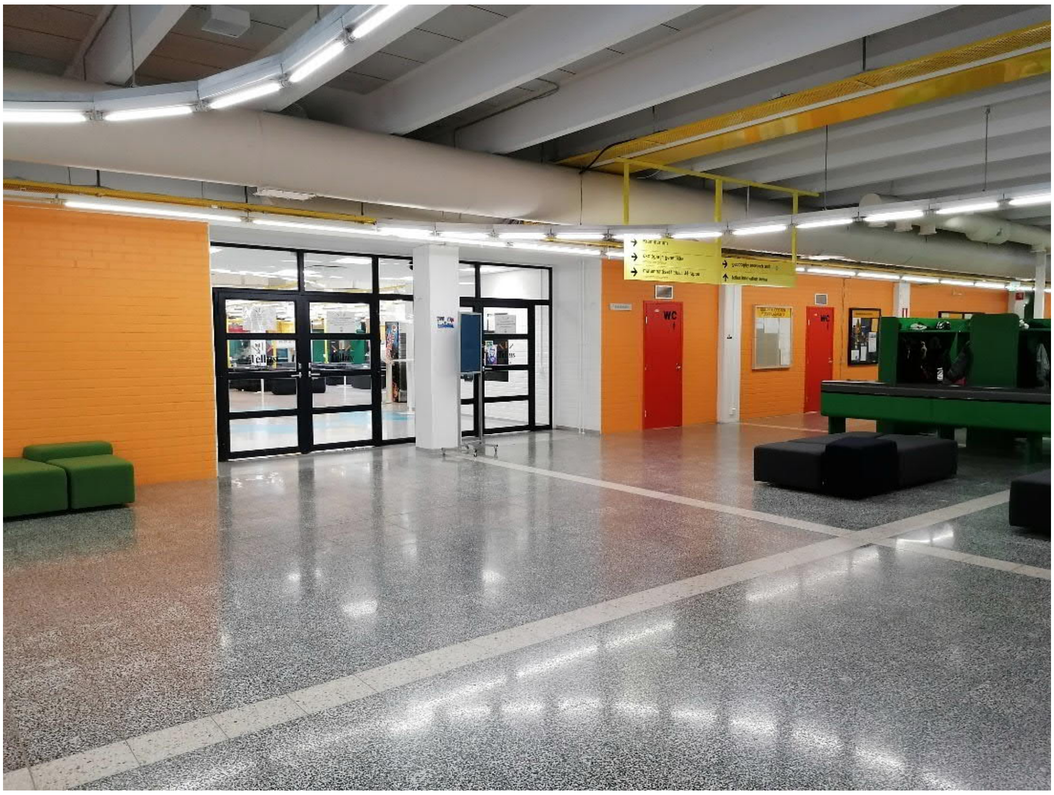


Figure 1. The main entrance of Tellus.

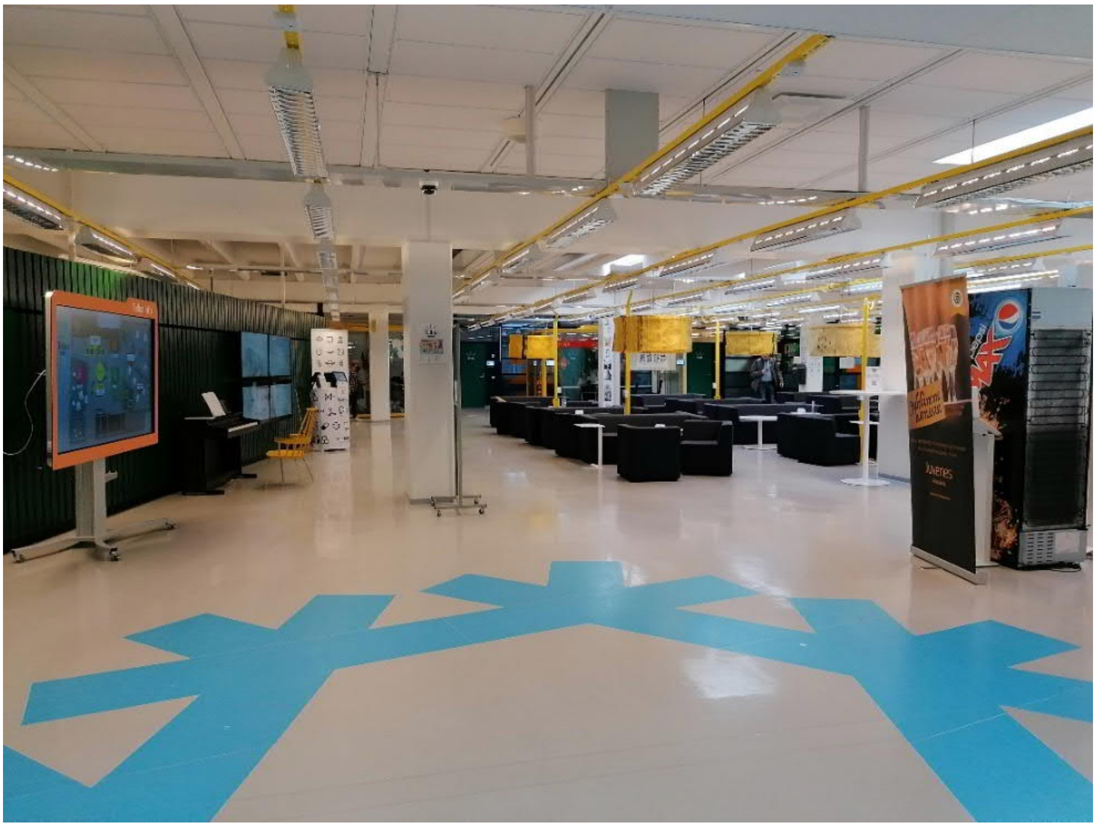


Figure 2. Tellus from the main entrance.

Before the renovation in the late 2015, Tellus used to be a library. It contained the collections of the faculties of technology and science as well as spaces for group and solitary work [9]. The design of the new Tellus was carried out by architectural office Kanttia2, and the space got the name TellUs Innovation Arena. In 2019, the name was changed to just Tellus. The space was designed to support networking, collaboration, and entrepreneurship, which is evident in the open layouts and wide views [10]. This is also reinforced by the freely movable furniture and adjustable spaces. The latest layout of Tellus is shown in Figure 3. The following chapters describe some of the spaces located in Tellus.

Figure 3. The map of Tellus. Note: Business Kitchen is now called Backstage. [11]

1.4.1 Café Tellus

In the heart of the Tellus, next to the main entrances, is Café Tellus, shown in Figure 4. It contains table groups with sofas and chairs, which can be easily moved around on their wheels, introducing an organic liveliness to the space. Café Tellus has a cafeteria, which serves snacks and drinks. Café Tellus area is occasionally used for events and art exhibitions, allowing the space to be used in various ways.

Figure 4. Café Tellus.

1.4.2 The Cubes

The cubes, shown in Figure 5, are small working spaces with chairs for four people. However, it is not rare to see the cubes being used by a single person, or in some cases up to five or six people. The cubes were manufactured by Vetrospace Oy. The cubes have glass walls, dimmable lighting, and adjustable air conditioning. Some of the cubes have monitors for connecting computer. Located next to some relatively noisy areas like Tellus Stage and the café, they manage to provide sound insulation, which increases privacy. There are four cubes in the international avenue and two between Nest and Backstage. Due to their popularity, the cubes need to be reserved for maximum of two hours at a time.

Figure 5. The cubes in the International Avenue.

1.4.3 Meeting Rooms

There are six dedicated meeting rooms in Tellus for everyone to reserve and use: Aspire, Brisk, Chill, Frost, Galaxy, and Horizon. They vary in size and included equipment. Aspire has a wooden paneling, and it is the most presentable and designed room for up to 20 people. Brisk and Chill are more traditional meeting rooms with space for 10 and 6 people, as shown in Figure 6 and Figure 7, respectively. Frost has a more casual decoration with a large art installation on the wall as well as sofas and small tables, as opposed to furniture better suited for desk work. Galaxy is a showroom with several large monitors to display information such as the environmental sensor readings and current research projects. Horizon is a meeting room for 16 people with a high-quality screen for presentations.

Figure 6. The meeting room Brisk.

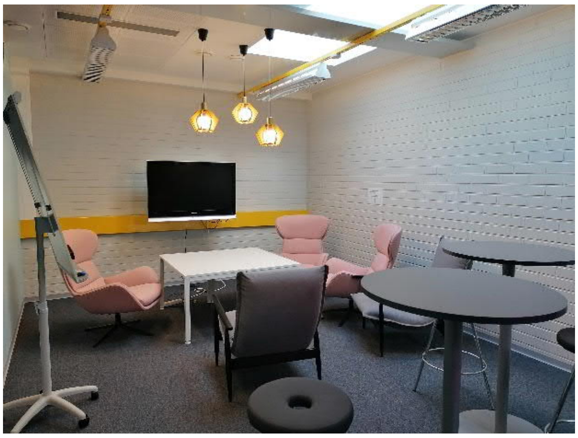


Figure 7. The meeting room Chill.

1.4.4 Tellus Stage

Tellus Stage is the main presentation area in Tellus for various lectures and presentations for 70–100 persons, as shown in Figure 8. It has a large projector screen for presentations and table groups directed toward the stage. Tellus Stage's back wall by the university main corridor is constructed out of glass and passers-by are often intrigued by what events take place in Stage.

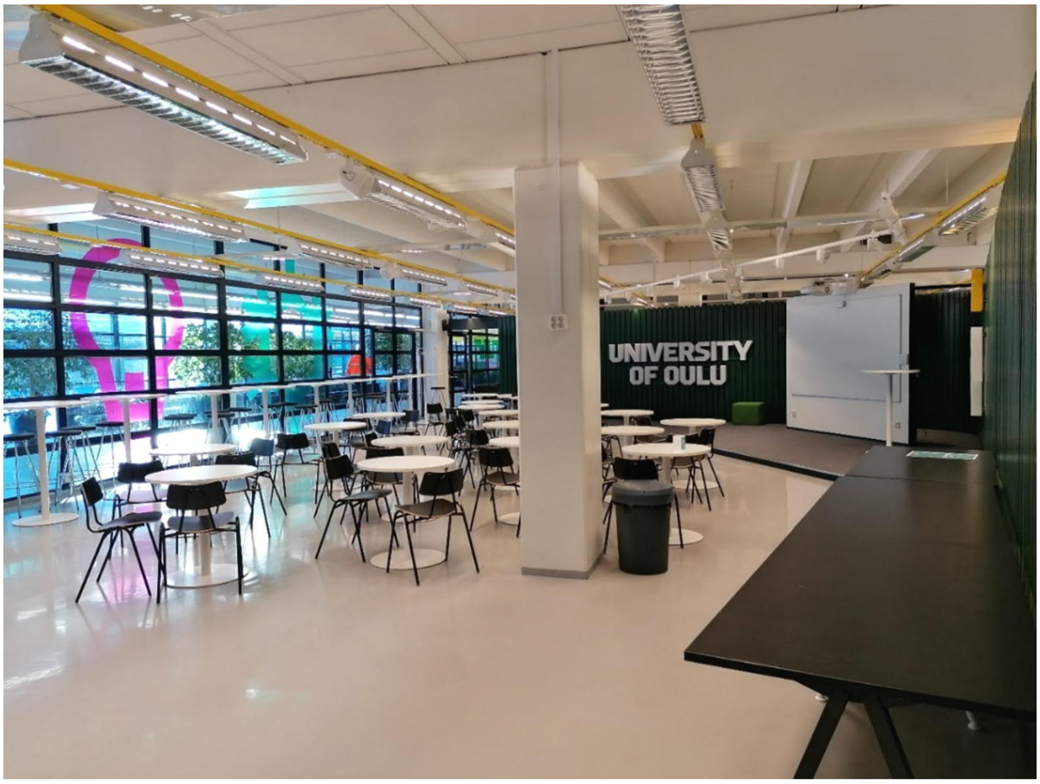


Figure 8. Tellus Stage.

1.4.5 Backstage

Backstage, shown in Figure 9, and previously known as Business Kitchen, is a space for group work, events, and presentations. It has the second largest stage in Tellus, after the Tellus Stage. The modular table groups support facilitation of various workshops and co-creation events. The far back end of Backstage has three booths with taller tables and chairs to support working while standing up or sitting down.

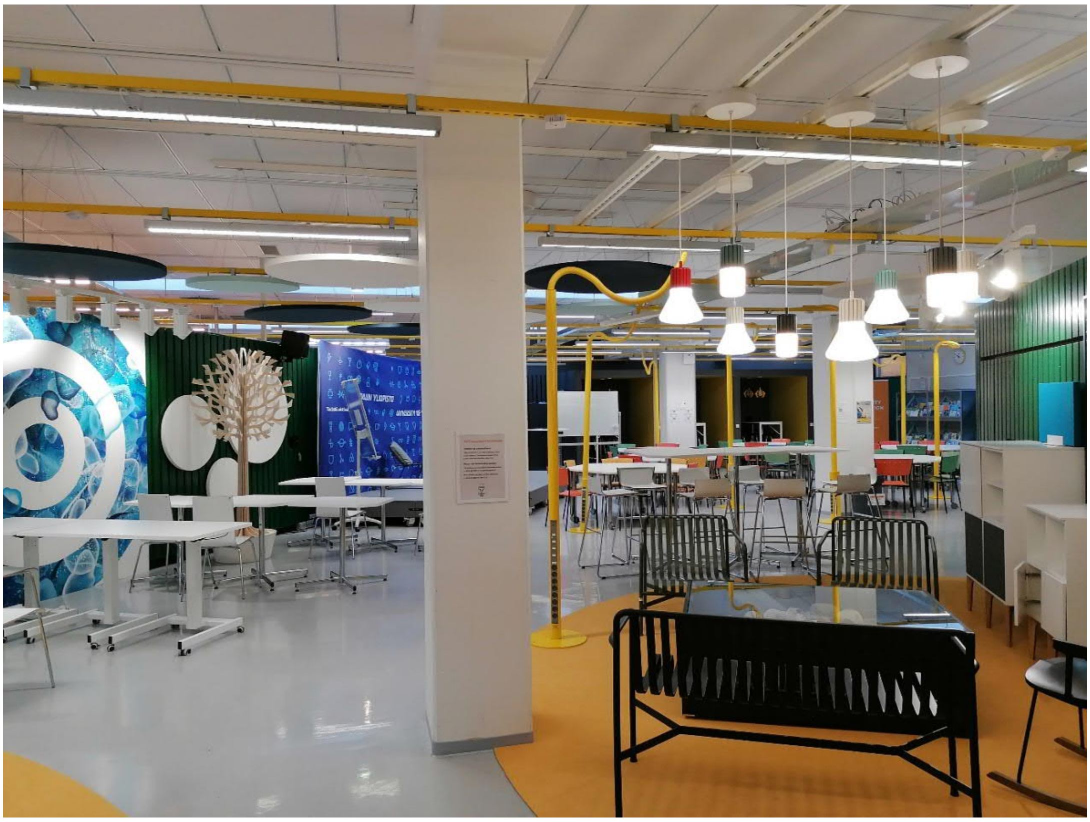


Figure 9. Backstage.

1.4.6 Park

Park is the main studying and group working area in Tellus. It has 18 computer stations next to the walls and modular table groups in the center. The prominent feature of the Park are the six cubes with integrated whiteboards in the outside and inside walls. The cubes are often used for group work, but also by individual people. The whiteboards are often used, which signifies the effective utilization of the resources.

Figure 10. Park.

1.4.7 Focus

Focus, shown in Figure 11, is a small space tucked between Nest and Backstage. It contains several height-adjustable tables with saddle chairs. The tables have felt screens on their three sides to decrease the amount of visual stimuli when working. Some of the tables have a LED light with controller for brightness and color temperature adjustment. There are also two cubes.

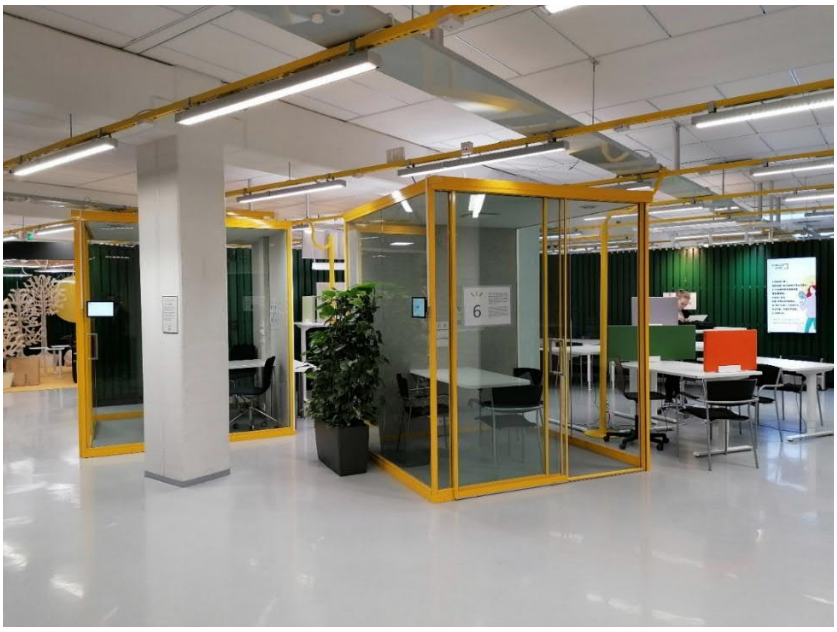


Figure 11. Focus.

1.4.8 Nest

Nest is a relaxation space in the center of Tellus, shown in Figure 12. It is advertised as a space for thinking and relaxing, which are essentially quieter, more introspective activities. Nest has bean bags for sitting or lying down, dimmed lighting, and a wooden floor and wall paneling, and the users of the space are instructed to take off their shoes. These factors suggest a calming, home-like environment, not only because in Finland shoes are not used indoors.

Figure 12. Nest.

1.4.9 Tellus Service Point and Staff Office

Service Point is a place where you can reserve Tellus spaces, loan equipment like adapters, a webcam, or a laptop, or get assistance in any Tellus-related matters. Staff Office is for the Tellus personnel to work in.

Figure 13. Tellus Service Point and Staff Office.

1.5 Multi-Spaces

As the aspects of work evolve, so do the places where the work takes place in. Throughout the decades, knowledge work has been transformed from traditional cell offices to open-plan spaces. This has been mostly due to the push for more efficient space utilization, which is a cost-saving method for the employer. Additionally, working in open spaces is said to promote collaboration and productivity. The downsides are associated with a lack of privacy, extra noise, and increased cognitive load. [12] Moving to multi-spaces have also been reported to increase the amount of communication [13].

In this study it is argued that analyzing, understanding, and using the multi-spaces require new conceptual tools. Multi-spaces are spaces with no definite functionalities or established norms. On the other hand, the flexibility allows for variety of implementations which can result in equally varying results.

As Tellus contains several areas each for several purposes, it can be treated as a multi-space. Furthermore, in this thesis, the multi-space is not limited to working in different contexts, but it is applied also to activities of recovery and socializing. The open layout of the space supports communication and sharing of ideas and knowledge. The furniture can be adjusted to the needs of its users. Chance encounters are also encouraged to aim the production of new ideas and innovations.

2 SENSOR TECHNOLOGY

With the rising popularity of Internet of Things technology, building automation has been one area where remote sensors have proven to be useful. The possibility to record large amounts of objective data remotely over time has brought a new focus towards data-driven fields. The sensors are often connected into a larger system, and depending on the system, it can handle the data gathering, analyzation, and automation of certain processes.

2.1 Environmental Sensors

Indoor environmental sensors can be used for several applications. For example, they can improve the safety, comfortability, and security in terms of gas detection, temperature control, and occupancy detection respectively. These different sensor systems can work independently, together, or as a part of a larger system.

Environmental sensors are types of sensors capable of measuring various factors of surrounding environment, both indoors and outdoors. These include factors such as carbon dioxide concentrations, relative humidity, temperature, and sound levels. These pieces of data can be used to evaluate certain factors. As such, the sensor data can provide one perspective on the quality of the space. For example, in an office, the air needs to change often enough to ensure that the environment is comfortable. Otherwise, it can cause symptoms like coldness, headache, and sleepiness.

2.2 System Description

To use the environmental sensors, they need be connected to a network for data gathering. The environmental sensors in the Tellus are part of a larger system in the University of Oulu. They are connected to the university's servers. The following chapters describe how the sensor system works, and how the data is gathered from the sensor to the database and transferred to the end client.

2.2.1 Sensors

The installed indoor environmental sensors are model ERS CO_2 manufactured by Elsys [14]. The sensor datasheet is presented in Appendix 1. The sensors can measure CO_2 levels, temperature, relative humidity, light, and motion (passive infrared, PIR). The sensors are battery-powered and installed in metal conduits which run on the ceiling of Tellus. There are in total of 330 installed sensors in Tellus.

As for the ERS CO_2 specifications, the datasheet lists suitable applications as indoor environment measuring, smart buildings, workplace management, and room occupancy. The sensor case is 86x86x28mm and weighs 120g with batteries. It is powered by two 3.6 V AA lithium batteries, and the expected battery life is up to 10 years. The sampling rate can be adjusted, and in the current case the data is polled every 15 minutes. The sensor model is shown in Figure 14.

Figure 14. Elsys ERS CO_2 sensor [14].

2.2.2 Network

To gather data from the Elsys IoT sensors they need to be connected to a network. The sensors in Tellus are connected to the University of Oulu 5G test network. To connect the sensors and the university server, a MQTT protocol is used. The MQTT protocol utilizes publish–subscribe pattern where devices react to the data based on certain topics [15]. For example, a change in temperature sensor's reading publishes a message with a topic of "temperature", which in turn causes a heating system subscribed to the "temperature" topic to get that data and act accordingly. These messages are handled by the MQTT broker, which serves as a central node between the sensors, the actuators, and the server where the data is stored and processed. The system is described in Figure 15.

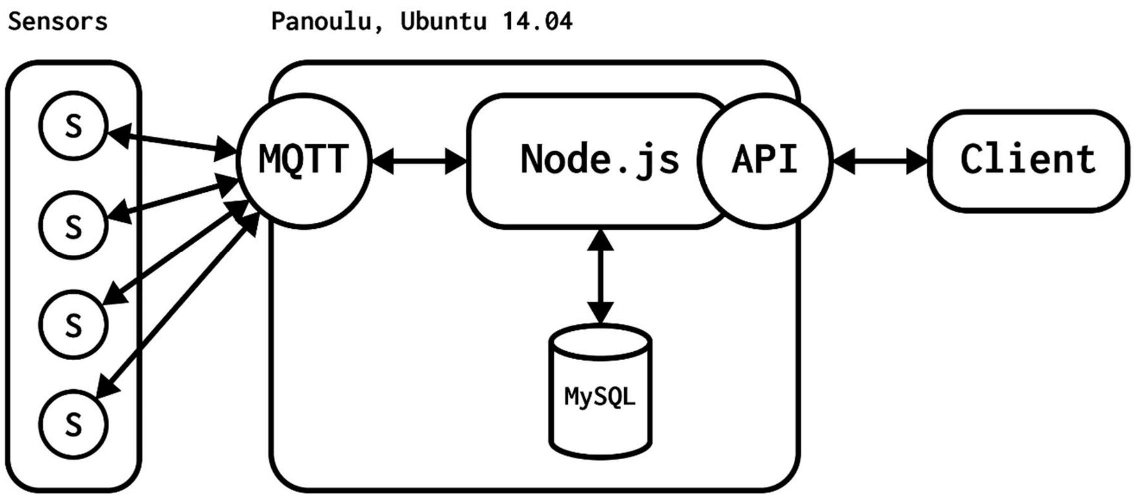


Figure 15. Description of the sensor network.

The MQTT broker is in the panoulu server of the University of Oulu and runs on Ubuntu 14.04 operating system. The server contains a MySQL database where the sensor information is stored. The server runs a MQTT Python client which gathers the sensor information and then inserts it into the MySQL database.

2.2.3 Data

A client can access the sensor data in the panoulu server through its REST API. Sending a GET request with the timeframe as the query parameter returns the sensor data formatted in a JSON file format, as shown in Figure 16. It contains parameters for the device id, timestamp, battery level, CO_2, relative humidity, light level, motion detection, and temperature level. The 15-minute polling rate is suitable for environmental parameters that change quite slowly, but for motion detection, that needs to correspond to the present moment.


```json
{
    "id": "a8-17-58-ff-fe-03-0f-56",
    "timestamp": "2020-01-20 08:56:05.201",
    "battery": 3.69000006,
    "co2": 335,
    "humidity": 24,
    "light": 346,
    "pir": 8,
    "temperature": 20.0
},
```


Figure 16. An example of the sensor data format.

3 HUMANS IN SPACE

Humans and spaces as subjects are widely covered in literature, and this chapter serves only as a brief introduction to some of the themes which are relevant for this thesis. The covered themes are in no way thorough or represent the general scope of the research in the topic of spatial experience. The spaces can on the one hand be very personal, intimate, and experience-forming for humans. On the other hand, they are a political way to organize different aspects of life. The following chapter highlights the aspects relevant to the study.

Inhabiting a space is wider and deeper phenomenon than the geometric connotation might suggest. Space is understood differently in various contexts. For a large part of the history of the Western thought “the general feeling was that the concept of space was ultimately a mathematical one” [16], as noted by Henri Lefebvre. The Cartesian mindset has slowly given way to more dimensions than three, and spatial research has started to consider aspects such as memories and emotion. These can make one space feel safe for someone, but repulsive for others. The same room can feel small on some days and large on others.

In the field of architecture, understanding of spaces is vital to produce spatial experiences with desired outcomes. However, there is no set way in architecture to describe and utilize spaces. The exact computer-aided designs have a clear sense of mathematical precision, while spatial experience follows a different dimensionality. The two dimensions of paper contain the spatial experience which is translated by the experienced eye and hand of the designer. And as thinkers like Juhani Pallasmaa have noted, the modern focus on the eye has brought it unbeneficial power [17]. The overemphasis on visual qualities undermines the extent of our sensory system and the holistic way we experience life. As such, experiencing architectural spaces is less about mathematical precision and more about the multisensory totality.

To summarize, the following chapter aims to argue against the Cartesian approach in spatial understanding and the disconnected duality of the mind and the body. The Sloterdijk’s foam theory is combined with the concept of porosity to introduce a conceptual language to help analyze the spaces in a more meaningful way.

3.1 Being Human

Most of the literature on spatial experiences start from the human and the senses. This focus on the perception and experiential qualities is relevant in the field of phenomenology as well. The joint exploration of the mind, the body, and the world allows for holistic understanding of human experience. In this way, the human experiences are as much bodily as they are products of the mind.

3.1.1 Perception of Space

The world outside any being is accessible to them through senses. The type and the quality of these senses provide a holistic experience unique to that being. Our senses co-operate to allow us to make sense of the world and navigate in it. Colors outside of the visible spectrum are unknown to us, and we are not guided by magnetic fields like some birds are. It would be a difficult task to describe qualitatively to what extent our sensory system is capable of understanding the world as it is, so this thesis only considers the basic senses and their roles in everyday life.

The basic five senses are vision, hearing, touch, taste, and smell. Throughout the human history, these senses have been utilized differently, and in the modern time, the vision is arguably most prevalent. For spatial perception, vision and hearing have a role in how a person orients and understands surroundings. A sound of a car can alert a person of danger and seeing a crosswalk lets a person know where to cross the busy street. The smell of a familiar café can bring a sense of warmth and intimacy. When extending the topic of spaces further into the realm of atmospheres, we are introduced to new sensations like "orientation, gravity, balance, stability, motion, duration, continuity, scale and illumination" [18], as stated by Finnish architect Juhani Pallasmaa. A single sense alone is wondrously expansive. Taking all these sensations together introduces a polyphonic bodily experience full of subtleties and extremes. The following chapters briefly describe the sensory qualities of the eye, the ear, the nose, and the skin.

3.1.1.1 The Eye

The eyes are the last to evolve and also the most complex of human sensory apparatus [19]. The eyes allow you to identify the external world, navigate in it, and act accordingly. The existence of mirrors alone reinforces the people's need to place themselves in the world. As such, seeing is a form of communication with the world. As art critic John Berger put this: "If we accept that we can see that hill over there, we propose that from that hill we can be seen. The reciprocal nature of vision is more fundamental than that of spoken dialogue" [20].

The eye allows for intention: the turning of the neck, the movement of eyeballs, and the focus of the pupil establish the action of seeing. To look and to see are a matter of choice, whether conscious or not. As such, the act of looking can be understood in various ways. It can be curious, hostile, inviting, or disconnected, among other things.

3.1.1.2 The Ear

Both the ear and the eye are used to evaluate distances. The ear picks up the surrounding soundscape and forms an understanding of the size and the quality of the space where a person is presently located. The echoes of a long unfurnished hallway are very different from a small bedroom with layers of soft textures. The ear can process information only from its immediate surroundings, whereas the eye can see further than the stars. One can consider the technological development of radio and television to realize how much simpler it is to produce a meaningful sound than a moving picture. Nonetheless, the ear can pick up very nuanced elements from the environment, like the heaviness of a step or an overheard tidbit of a casual conversation.

Privacy is not attributed only to what can be seen: neighbors' sounds can make you aware of your thin walls. Your own actions are in return determined by what you let others to hear. In an open-plan office one might feel distracted by ever-present sounds, whereas a beach with a joyous and playful chatter can feel uplifting. The subjective experience of sounds also implies that one person's sound is another one's noise.

3.1.1.3 The Nose

The olfactory system, that is, the system concerned with smell and taste, differs greatly from other senses [21]. The smell is directly connected to the limbic system, which is one of the oldest systems in human brain. The limbic system is also responsible for memory and emotion. As such, it can produce some of the most vivid sensory experiences. The strength of the olfactory system can be further reinforced by the existence of pheromones. They are “pollenlike chemicals that when emitted by one creature they have some effect on other members of the same species” [22]. A material can travel through air into a human to produce some emotional response.

In the context of northern Europe, the smell is a sense to be suppressed and avoided. The ideal smellscape seems to be a neutral, that doesn’t distract the everyday life. Edward T. Hall states that the olfactory experiences in the northern Europe and the northern America are bland and aptly describes the power of scent: “entering a taxicab, they [Americans traveling abroad] are overwhelmed by the inescapable presence of the driver, whose olfactory aura fills the cab” [19]. The cultural context is vital in understanding the usage of the smells, and in multi-cultural situations the smellscape can be perceived in very different ways.

3.1.1.4 The Skin

The skin is capable of measuring the most immediate distances of the human sensory range. It senses the direct touch or the subtle wind, and it can act as a social extension of the body through the hands. It is also able to detect heat, pain, and pressure. Touch of a loved one feels different from others, and an icy patch under the wheel of a bike signals the rider to be more careful. As such, touch forms an immediate relationship between the self and the world. Hall writes: “The hardened, armorlike resistance to the unwanted touch, or the exciting, ever-changing textures of the skin during love-making, and the velvet quality of satisfaction afterward are messages of one body to another that have universal meanings” [19].

Textures, too, provide a sense of the world. A smooth pebble on the hand is “time turned into shape” [17]. A polished object tells a story and establishes a sense of time. A glazed soup bowl shares its warmth through its ceramic skin. Beginner guitarists suffer from sore fingertips, but with time the callous tips grow more resistant to the guitar strings.

3.1.2 Affect

Affect is a term closely linked to terms like mood and emotion. In the field of psychology, there are various definitions and ways to use these terms. Affect is characterized as a “state of pleasure or discontentment felt with some degree of activation” by Ana [23]. In comparison, emotions are shorter duration events brought by certain situations or affective feelings. A mood is vaguer than an emotion and can last longer. The cause of a certain mood is less definite, and it is less intense. As such, affect, emotion, and mood are linked together, but they are by no means synonyms.

Human experience is in constant change, and a person’s current state affects their perception and outlook. When feeling irritated, unpleasant sounds can seem more annoying than usual. On the contrary, in a calmer state of mind one might be more willing to forego certain responses towards unpleasant stimuli. As such, when assessing spatial experiences, it is beneficial to understand the person's affective state to form a more thorough understanding. Furthermore, it has been shown that person's context can affect their emotion, and contextual aspects can be used to recognize person's emotion [24].

3.2 Being in a Space

The other half of spatial experience consists of understanding spaces. The word "space" has several meanings depending on the subject matter. It can refer to architecture, mathematics, outer space, or social sciences, and be combined with terms like private, public, mental, and social. As such, it is the difficult to use the word consciously with the relevant connotations it can carry. When talking about architectural spaces, purely geometric interpretation isn't sufficient to describe the spatial experience of a person. German philosopher Martin Heidegger described this difficulty: "The mathematically-cleared space may be called *the* space. But the space in this sense, contains no spaces and no places. We never find in it any *locations*, that is, *things* of the kind the bridge is" (italics in original) [25]. As the Figure 17 shows, the spatial experiences of being in shade, in a crowd, and in the open sun vary significantly.

Figure 17. Humans inhabit spaces. [26]

Humans are spatial creatures, and not the least because we exist in space. We organize and divide our surrounding space into smaller spaces to better suit our needs. There are spaces important to us and spaces we forget. Ones we pass by and ones fit for dwelling. Spaces can be used to control the flow of people or labor. Whatever the perspective is, the relationship between humans and space is inseparable. “When we speak of humans and *space*, it sounds as though humans stood on one side and *space* on the other. But *space* is not something that stands opposite to people” (italics in original) [25], Heidegger states. He has formed this into a term *being-in-the-world* (German: In-der-Welt-sein), which bridges the void between the subject and the object.

In this thesis, in order to understand spaces, a suitable language and conceptual metaphors have to be employed to allow for an explicating perspective. It utilizes the foam theory from Peter Sloterdijk with the concept of porosity from Nancy Tuana. This has enabled to treat being in a space through the lens of smaller subdivisions of spaces, their mutual interactions, and the experience of being in them. Furthermore, this perspective guides the process through which the user experiences are gathered and analyzed.

3.2.1 Spaces in Context

We go through multitude of spaces in our lives. They all provide some purpose for existing, whether by a deliberate design or by personal repurposing. Home is our first space, and from there we direct our life into various directions while occasionally returning to the dwelling of home. “The truck driver is at home on the highway, but does not have a shelter there; the worker is at home in the spinning mill, but does not have a dwelling place there either; the chief engineer is at home in the power station, but also does not dwell there”, expresses Heidegger [25].

The question is: how spaces can be understood? Typically, spaces are categorized by their function: a bedroom, a bus stop, and a basketball field all exist to provide a physical location for an activity. Now, this is not to say that each physical location, a space, contains an intended function, or vice versa. Often times a space may contain several functions for activity: a park can host all sorts of activities such as playing, sunbathing, picnicking, and more. As such, it is not sensible to study spaces purely from the perspective of their intended purpose.

Alongside the dominant spaces, there are spaces that connect them or exist outside of them. These “spaces in-between” are called liminal spaces, as described by Shortt [27]. In her article, she explores various meaningful spaces used by workers. She gathered photographs from liminal spaces such as “cupboards, toilets, stairwells, and doorways” [27]. These liminal spaces became spaces of “creativity and inspiration” [27] while providing “dwelling places for privacy” [27].

As these previous examples show, spaces can be used for various activities but also to avoid doing certain activities. A person might stay in a more hidden area of the workplace to avoid being seen and to gather themselves. In this way, the identity of the individual is also relevant: different spaces support different roles a person takes. A service desk worker might experience great deal of emotional labor which necessitates a space for restoration and relaxation during the workday. As such, spaces can enable identity management and to orient one’s *self* in a work setting.

A space can also have certain qualities which require certain mood from its users. De Paoli et al. studied different organizations and their spatial contexts [28]. Companies aiming to foster creativity might look towards designing their workspaces to achieve those goals. An aspect brought up is that “current creative workspaces seem to be designed for extroverts with a high tolerance of noise and distraction”. In that sense, spaces can be understood in terms of introversion vs. extroversion, that is, what kind of social presence is expected from the users of the space. For example, it is suggested that extroversion is positively associated with the openness of the area [29].

When it comes to multi-spaces, these aforementioned facets can cause difficulties. The fuzziness of the worker’s role or possible activities requires new conceptual ways to understand the spaces, both for the users and the designers. The spaces should support the needs of its users while providing options for flexible ways of working.

3.2.2 Affordances

Affordance is a theory developed by psychologist James J. Gibson, and it describes the process of assessing one’s surroundings to form an understanding of possible actions. “The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill.” [30]. In Gibson’s definition, the environment contains, but is not limited to, the medium (air), the substance (water, tissue, clay), the surface (ground, stream, wall), the objects (sheet, clothing, tool), other persons and animals (mother, pet), and the places (hiding place, workplace, home). For example, the tools in Figure 17a communicate visually how they should be held, and the jaws of the tools imply certain actions the tool can be used for. The bench in Figure 17b functions as a surface which affords sitting and admiring the mountain view. Affordance is a term used in various fields, such as psychology, industrial design, HCI, interaction design, and artificial intelligence.

(a) The form of a tool suggests its affordances. [31]

(b) A flat surface implies it can be used to sit on. [32]

Figure 18. The affordances of tools and surfaces.

When talking about terrestrial surfaces, Gibson refers their affordances as “climb-on-able or fall-off-able or get-underneath-able or bump-into-able”. The individual perceives the environment as possessing these types of characters. Utilizing this line of thinking in the field of architecture, the different affordances in multi-spaces could then be described with words like relax-on-able, silently-work-in-able, and socialize-with-able. For example, it was studied by Backhouse et al. how “available” the workers of an architectural design office are in moving around on their feet or sitting down at their desk [33]. In terms of affordances, the perceived state of another person in an office determines the affordances for interruption and social interaction.

In the multi-space context of this study, the spaces allow for various uses, and affordances can be used to understand how users understand these possibilities. Café Tellus can afford relaxation or working, depending on the person. The actual use of the space might be different from what was planned, which necessitates studying the space after it came into use to ensure the outcome is as intended. As such, the research has to be done using the end-user experiences while designing the information gathering process appropriately.

3.2.3 Atmosphere

As a move away from the geometric understanding of spaces, I utilize the concept of atmosphere to describe the holistic experience of spatiality. The origin of the term comes from Latin, as *atmós* + *sphaera*, meaning steamy or a gaseous sphere. It related to the air surrounding the Earth, and later it was utilized to describe the quality of air in a specific space. An atmosphere is instantaneously transformed in an event of fire, as shown in Figure 19, witnessing the immense communicative power of a hostile atmosphere. In this thesis, the atmosphere of Tellus is researched in terms of certain defined spaces in it.

Figure 19. Atmosphere can communicate vividly. [34]

In literature, the research on atmospheres ranges greatly from theoretical descriptions [35], subjective depictions [36], and simulatory explications [37] to real-life measurement setups

[38]. As Borch notes, “the notion of ‘atmospheres’ is exceptionally slippery” [39], which motivates the research to form a better understanding of it.

One of the most important points about experiencing atmospheres is that they are “experienced emotionally before they are understood intellectually”[18], as Pallasmaa states. He continues that experiencing atmospheres is a multisensory experience, containing sensations of seeing, hearing, touching, and so on. As such, experiencing atmospheres is a polyphonic event, where the total experience is more than the sum of its parts. The Figure 20 gives immediately an impression of dampness and protection. An essential motivation to pursue further understanding of atmospheres is that they can be designed to elicit a certain mood in a space, as stated by Böhme [35]. This reinforces the designer’s role in being the sensible and conscious creator of spaces.

The experience of space and atmosphere can trigger even deeper and more meaningful memories, which are outside of the designer’s reach. A familiar scent of a barn or a certain patina and dullness in wooden stairs can rejuvenate the person in an instant. As Bachelard describes, “[f]or a knowledge of intimacy, localization in the spaces of our intimacy is more urgent than determination of dates.” [40] Our most vivid daydreams and memories reside in spaces familiar and most sensuously rich to us.

Figure 20. Atmosphere is experienced immediately. [41]

3.2.4 Foams

This thesis builds on the concept of foams developed by Sloterdijk in the last part of his magnum opus trilogy, *Spheres*. The first part, *Bubbles*, starts out from the existential nature of humans, and continues from the work of Heidegger by stating that existence is defined as being-in-spheres. In the second part Sloterdijk "traces the history of globalization as an expanding spherological consciousness" [42] from the ancient Greece through the first circumnavigation of the Earth to the present day. The last part of the trilogy regards the society as an agglomerate of bubbles, as the substance of foam.

The justification of utilizing a seemingly abstract and unconnected theory like this lies in the research process of this thesis. Examining of the various spaces in Tellus, and spaces in general, brought about a communicative difficulty to describe them through their usage, but also as separated yet connected entities. The work of Sloterdijk brought the necessary vocabulary to understand these aspects and the atmospheres, or "air conditions" of spaces. Furthermore, the dynamic aspects of the foam are well suited for the lively grouping and ungrouping of individuals in a space like Tellus. Sloterdijk states that "modern society is based on a two-beat rhythm-the disassembly of social conglomerates into individuated complex units and their recombination in cooperative ensembles" [7]. Borch has shown how the Sloterdijk's foam theory brings a new perspective to organization theory through its focus on atmospheres [8].

What gives the Sloterdijk's theory of bubbles and foam so much descriptive power is their topological aspects, in other words, the way the foam is understood spatially. As one example, Sloterdijk uses the modern place of dwelling, the apartment, as an image of the bubble and foam: "The modern apartment … materializes the tendency towards the formation of cells, which one can identify as the architectural and topological analogue of the individualism of modern society" [7]. These bubbles are described as "co-isolated" cells, which are defined by their shared separateness from others. It is this relationship that further strengthens the theory's descriptivity: the "shared membranes imply co-fragility" [42], resulting in spreading transformation of form in the foam structure if one bubble bursts. The Figure 21 illustrates these foam structures with fragile, co-isolated bubbles, a fractal-like organization.

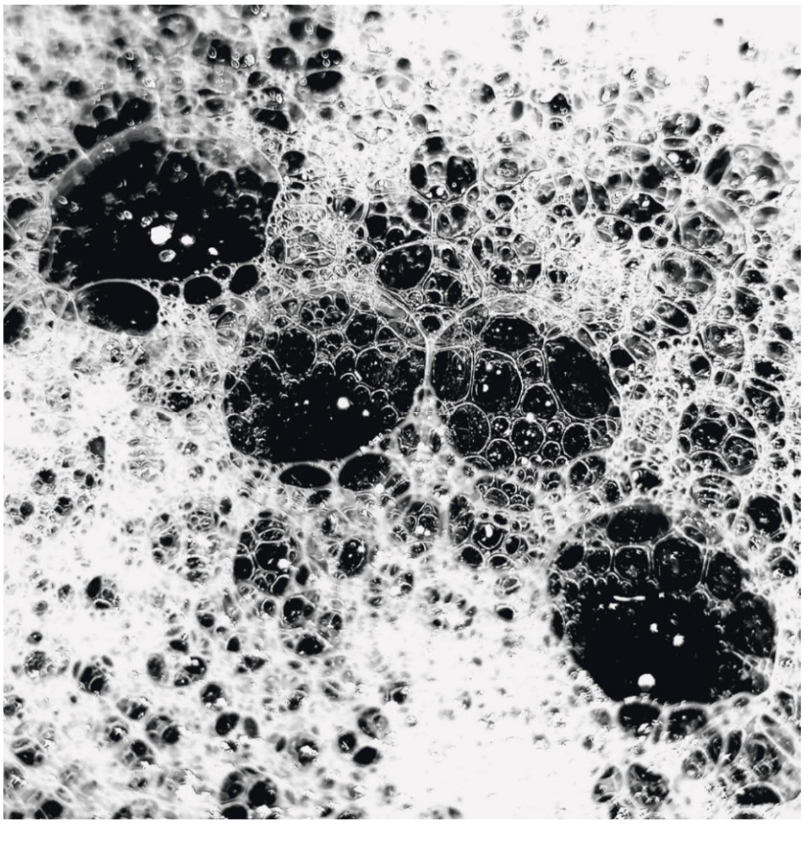


Figure 21. Foam.

When considering the multi-space as an organization of foam, the atmospheric aspects of Sloterdijk's sphereology rise to relevance. Understanding spaces as a formation of atmospheric bubbles of various sizes helps to analyze the spatial experiences of the users of the spaces, like in Figure 22. In the process of putting the theory of this thesis into practice, it differs from the Sloterdijk's theory as it focuses on the subjective experience of a single human. These aspects give insights into the bubbles of the space and their atmospheres. Furthermore, the theory suggests the usage of the space and gives thought to the development of organization of the space. The multi-spaces containing several affordances for activities is isomorphic to Sloterdijk's description: "modern collectives must face the task of producing spatial conditions in which the isolation of individuals on one side and the grouping of individuals into large ensembles for cooperation or contemplation on the other side are given support. This demands new deployments for architecture" [7].

Figure 22. Tables can be considered as co-existing bubbles in a larger co-isolated bubble of the library and the outdoors. [43]

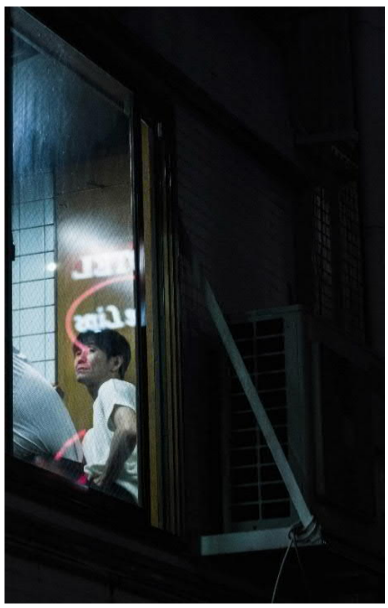
3.2.5 Porosity

Porosity is a term close to the essence of the foam theory but not used by Sloterdijk. One of the most prominent uses of the term comes from Benjamin Walter and Asja Lacis in their 1925 essay on Naples. They describe how in Naples the “buildings are used as a popular stage. They are all divided into innumerable, simultaneously animated theaters. Balcony, courtyard, window, gateway, staircase, roof are at the same time stage and boxes” [44]. The descriptions of Naples reinforce the usefulness of the term “porosity”. This aspect of the porosity of windows is visualized in Figure 23a and b. Further examples are in Figure 24 and Figure 25.

The second way this thesis was inspired by porosity is through the American philosopher Nancy Tuana’s essay on the aftermath of the Hurricane Katrina. She utilized “the conceptual metaphor of viscous porosity as a means to better understand the rich interactions between beings through which subjects are constituted out of relationality” [6]. In essence, she aims to bridge the gap between often separate sciences of nature and social world and urge towards a more interdisciplinary research. As such, its theme and approach are well suited for the present study. Tuana uses a vivid example on how microparticles of PVC pass through porous human skin and flesh, in short, “plastic becomes flesh” [6].

These examples of porosity illuminate the interactions between entities, how they can be applied to the foam theory, and how their mutual, co-separating membrane affords those. In talking about neighboring ties, Sloterdijk writes: “…if Einstein lived next door, I would not know any more about the universe as a result. If the son of God and I had lived on the same floor for years, I would only learn afterwards, who my neighbor was” [7], which aptly describes the co-isolated aspect of homes as bubbles and how information isn’t actively transmitted, regardless of the short distance. To state more briefly, co-existing bubbles share a porous membrane, which affords a certain set of interactivities.

(a) Curtains afford controlling porosity. [45]



(b) The view from a window is simultaneously bidirectional. [46]

Figure 23. Porosity can be understood in various ways.

In a multi-space, this definition of porosity can be utilized in the ways different sensations carry through the bubbles formed in the space. To finally explicate the descriptive power of these previously introduced concepts, I will use an open-plan office as an example. Each desk section can be understood in terms of single bubbles, forming a foam with their neighboring ones. A loud, distracting telephone call carries out to surrounding bubbles, causing a loss of concentration, unless the aural porosity is reduced through the affordance of ear plugs or noise cancelling headphones. A scent of a colleague walking by creates an affective response, reminding of another person from their own life, from way back. These sensations are unreachable to the break room, where the coffee drips quietly.

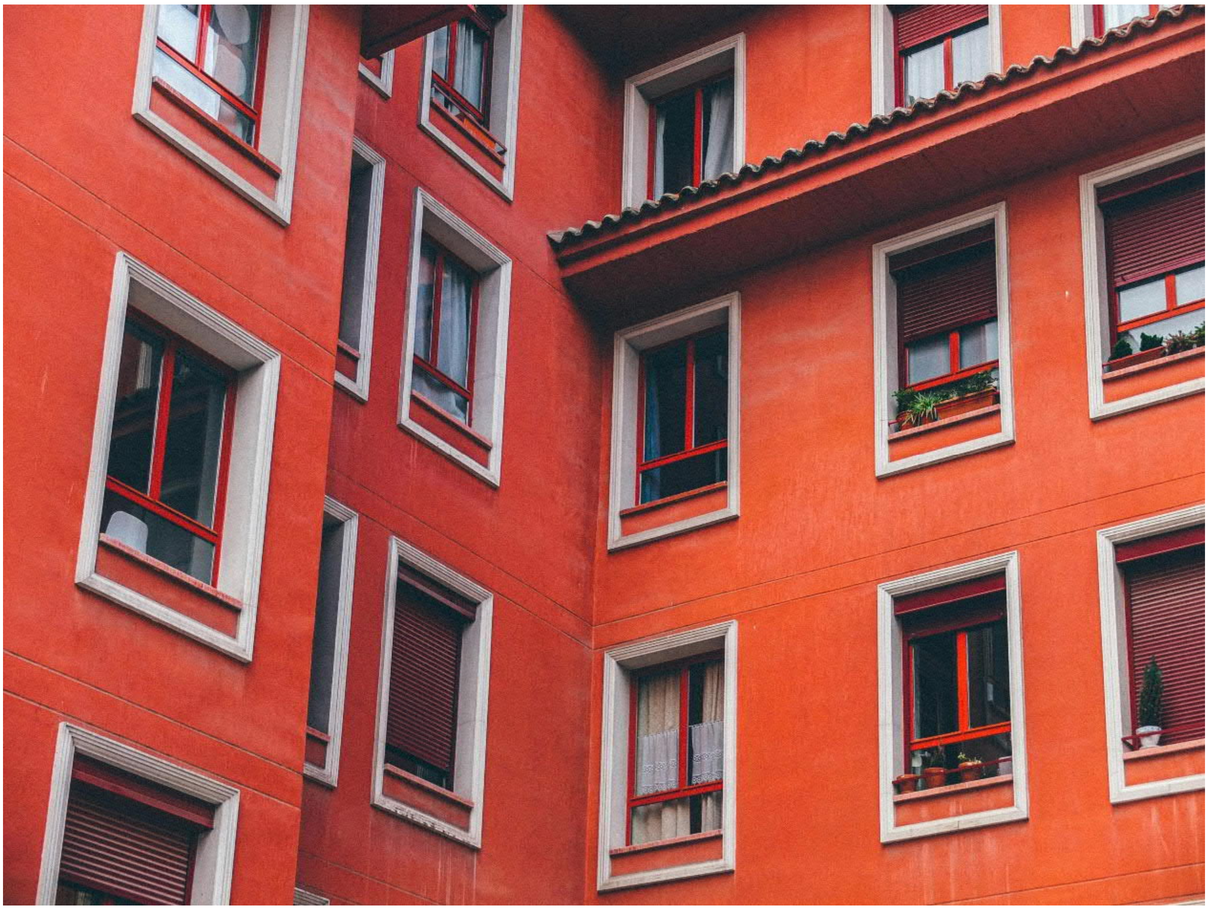


Figure 24. Buildings' porosity is made explicit through windows. The amount of light, smells, and noise can be adjusted through the act of opening a window. [47]

Figure 25. The porosity of the air allows the warm water to condition the room's air steamy. [48]

4 DATA GATHERING

The utilization of subjective experience and objective sensor data has specific requirements for data gathering. Together these form an understanding of the space and its users. The sensor data functions as the backdrop against which the user data is reflected. Also, the spaces are compared with each other to see how the spaces differ in their functionality and how they are experienced.

Research has shown that memory can change the affective experience, which in turn necessitates certain ways the data can be gathered [23]. To gain a snapshot of the spatial experience, the survey needs to happen in the context where the space is experienced by the people. Furthermore, the survey needs to be short, accurate, and informative, and it should result in data which can be used to make meaningful assessments of the space.

This leads to the development of a suitable survey. Due to the prevalence of internet-connected devices, using a browser-based solution allows to gather the online data. In comparison, an offline survey can be inconvenient to the respondent and the researcher. Furthermore, a browser-based solution provides an easy access to the survey without needing to download or install any applications.

The goal of the survey is to gather contextual data from the respondents' context and their subjective experiences of the space. The following chapters describe the development of the MoodFoam survey, from the specifications and the implementation to the sensor data collection method.

4.1 The MoodFoam Survey

The main guiding factors in the development of the MoodFoam survey are the way it is accessed, what type of data is collected, and how long it takes to participate. As previously mentioned, a browser-accessible survey allows for a lower threshold to participate. In a constantly changing layout of the multi-space of Tellus, it serves as a benefit to design the participation as effortless as possible.

The space in Tellus was analyzed through the survey to understand which places are experienced in a certain way and whether there are differences between the places. As a limitation of this design, the survey did not track the individual's experience throughout the timespan of the data gathering process. The survey used cookies to identify certain users and to keep track of unique participants. It is assumed, though, that the average user doesn't participate as often as compared to a case with recruited participants.

To gather a large enough sample size, the survey was available for two weeks. This allowed for a comparison between the weeks and increases the number of participants. Each participant could fill the survey as many times as they want during that two-week period.

4.1.1 Content

The essential data in the MoodFoam survey is the respondent's background information and their current context and spatial experience. For the background information, only respondent's role is relevant to the study. The ethnic background, sex, health, and other factors are left out of the scope of this study to keep the answering time at minimum.

It is necessary to gather the time and place of the respondents to understand the context where they are in the space and at what time. The time allows to understand when the participants were active and can also be used to synchronize the user data with the sensor data. Other aspects in the context are what the person is currently doing and with how many people. They allow to see how the different spaces are used and in what kind of groups of people.

The subjective aspects of the survey are related to the suitability of the location in regards of the activities, the person's affective state, and the experience of sensations of smell, sound, and temperature. These enable to understand the subjective experience of the sensations in the space.

4.1.2 Method

One of the main challenges in the survey design was to gather the location data effectively. In literature, there are several methods to achieve it and they perform differently depending on the context. The solutions can be divided into two categories of infrastructure-based and infrastructure-free, depending if extra systems are needed or not [49]. The different considered methods are presented in Table 1. The chosen method was inspired by Visualize Your Spatial Experience (VYSE) study [50], where museum exhibition visitors were asked to draw their path around the space and color each space based on their experience of the space.

Table 1. Indoor positioning methods for mobile devices and their suitability for the MoodFoam.

Method	Pros	Cons
Placing a marker on a map	Cost-effective Relatively easy implementation	User input required Precision depends on the user
Location information embedded in the URL	Cost-effective The location is gathered automatically Relatively easy implementation	Fixed location of the custom URLs determines the position resolution URL access method can provide difficulties
Bluetooth beacons	User input not required	Requires Bluetooth connectivity Moderate error (1 m to 2 m) [51] Longer time to develop
Wi-Fi location	User input not required	Requires three or more Wi-Fi access points [52] Requires Wi-Fi connectivity Relatively large error (6 m to 7 m) [51] Longer time to develop

For measuring affect, the literature presents several methods. Some of these are presented in Table 2. Affect evaluation methods and their suitability for the MoodFoam. Affect grid is best suited for cases where the interest is not in the individual subjects, but rather in the aggregate of the moods [53]. Affect grid contains two dimensions, valence, and arousal, to describe the mood. PANAS, and its several variants, such as I-PANAS-SF, are well-established, robust methods, with a larger item count [54]. There are also innovative approaches to mood assessment, like the 3D-projected hypercube [55]. It contains two more dimensions compared to the affect grid, allowing for a more fine-grained evaluation of emotions.

Table 2. Affect evaluation methods and their suitability for the MoodFoam.

Method	Pros	Cons
Affect grid [53]	Quick Well-utilized	Limited dimensions Complex emotions not easily definable Semantic interpretation can vary between subjects
3D hypercube-projection [55]	More accurate than affect grid	Hard to visualize Large item count (23)
PANAS [54]	Robust	Moderate item count (20)
I-PANAS-SF [56]	Better used for cross-cultural contexts	Smaller item count than in PANAS (12)

As the time to take the survey needs to be small, the affect grid contains a clear advantage over PANAS. In a lengthier study utilizing the PANAS or I-PANAS-SF could provide a more robust evaluation of mood.

4.1.3 The Selected Questions

The selected questions can be divided in three groups: background questions, context questions, and subjective questions. The background questions are about the respondent. The context questions bring understanding where and in what company the user is experiencing the space. Lastly, the subjective questions provide information on how each user experiences the space. The selected questions are shown in the Table 3.

Table 3. Order and content of the questions in the MoodFoam survey.

Question #	Question style	Question content
1.	Button	Welcome to the MoodFoam, please press the button below to start the survey.
2.	Button	This is a survey about your feelings and experiences in Tellus Café and cubes area. There are no right or wrong answers and all information is anonymous.
3.	Multi-choice	Who are you?
4.	Multi-select	What are you doing right now?
5.	Multi-choice	What size is the group you're in right now?
6.	Location	Where are you now?
7.	Likert-scale	How well does this spot support your current activity?
8.	Affect grid	Please rate how you are feeling right now.
9.	Button	How do you feel about the following statements?
10.	Likert-scale	The sound level does not bother me.
11.	Likert-scale	There are no distracting smells.
12.	Likert-scale	The temperature level is just fine.
13.	Button	Thank you for participating in the study!

Using the previous groupings, the question 3 represents the background information. The questions 4–6 are about the context, and the questions 7–12 focus on the subjective experience of the respondent. Along with this information, the time is saved to the responses. More precisely, the jsPsych plug-in saves the time it took to answer each question, and the server saves the time of day when the data is inserted to the database.

4.1.4 Implementation

The survey was implemented using the open source JavaScript library jsPsych [57]. It is designed to conduct behavioral experiments on the web browser, which allows for an easy access in various mobile devices. The experiment is structured to a timeline, which contains different tests of the experiment. The jsPsych library provides plug-ins which can be used for different kinds of experiments. These plug-ins include responses to buttons, sliders, images, and more. A template plug-in is also provided to create custom questions. The survey contains 13 questions, 11 of which utilize the existing plug-ins and two of which use custom plug-ins for the affect grid and location questions.

The jsPsych experiment runs on a Node.js server which is hosted in Heroku, a cloud application platform. The experiment data is stored to a Heroku PostgreSQL-database through the Node.js server. The experiment data can then be retrieved from the database using the Heroku web application.

Once the user has answered to every question and the data has been sent successfully, the user is redirected to a Google Forms site that manages the participation to the survey's prize lottery. The redirection is done using `window.location.replace(response.url)` function which replaces the browser history with the `moodfoam.com/end.html` page. This ensures the user does not accidentally go back to the survey page. The process is visualized in the sequence diagram in Figure 26.

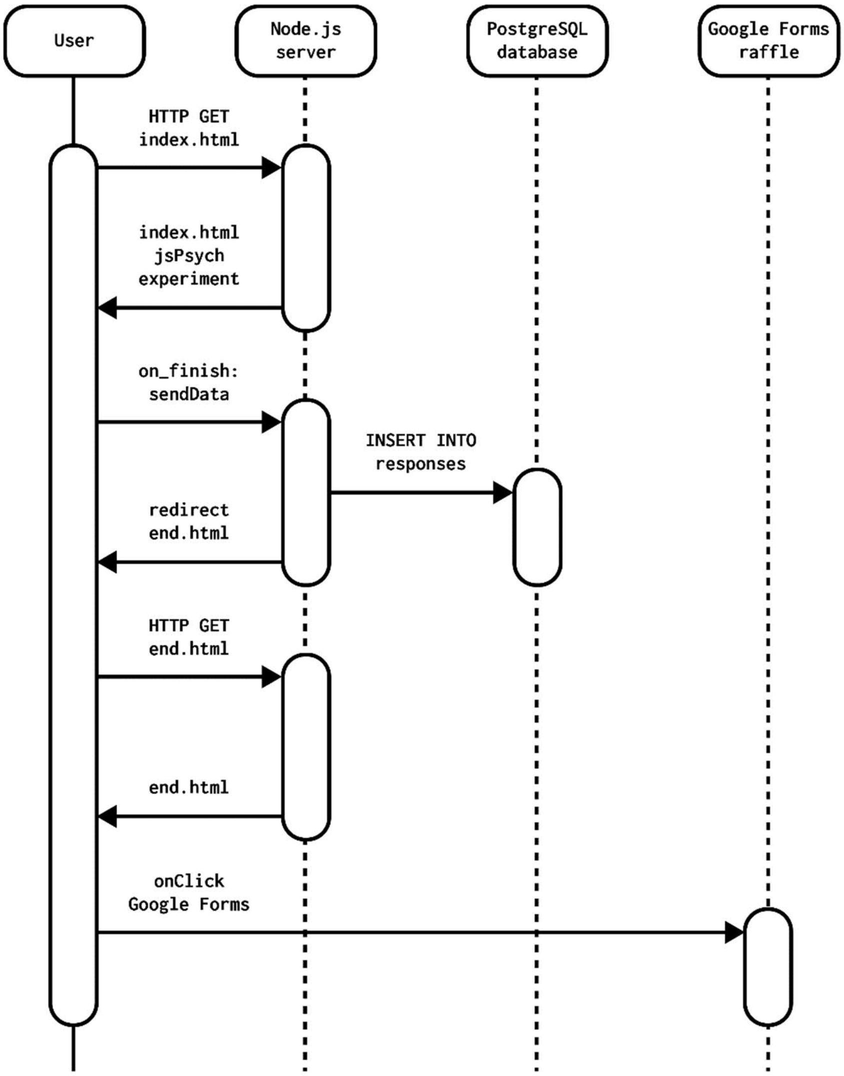


Figure 26. The sequence diagram for the MoodFoam web application.

4.1.4.1 The Location Plug-In

The location plug-in utilizes the Leaflet.js plug-in, which is an open-source JavaScript library for displaying interactive maps [58]. The layout is familiar from other map tools, such as Google Maps, which makes it intuitive to use on mobile and desktop devices. The user can zoom and pan the view around and place a marker to pinpoint their location, as shown in Figure 27. The marker location is saved as a latitude-longitude data pair relative to the map coordinates.

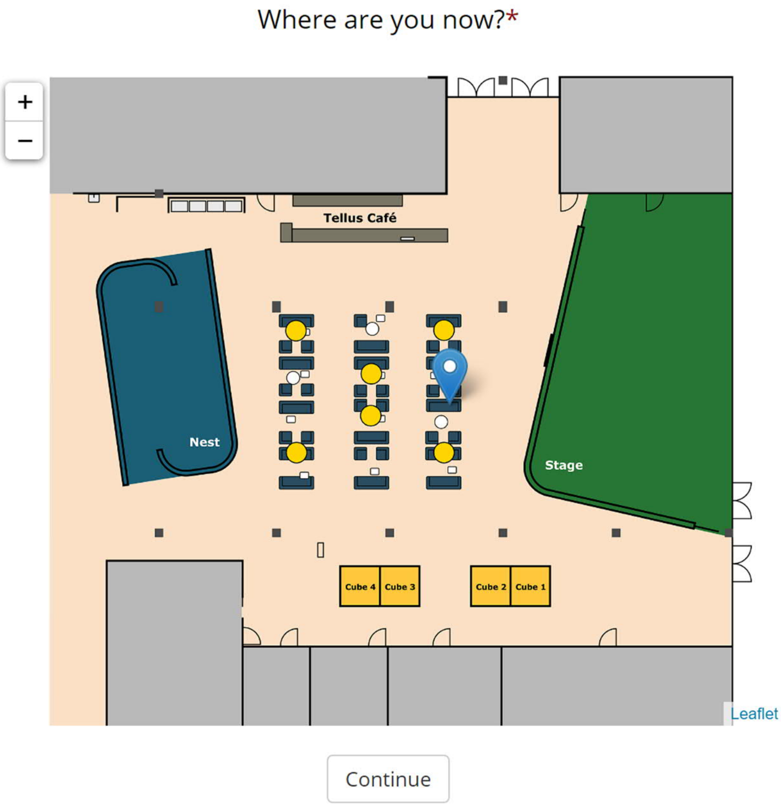


Figure 27. The location question and the Tellus map used in the survey.

The location plug-in has several parameters to use as described in Figure 28. The stimulus defines the used source image with the displayed width and height. The default zoom level is 11, but the initial zoom level can be defined as well. Preamble is the question shown above the map object. The required parameter is false by default, and it ensures that the user sets a marker down.

```
var test_location = {
  type: "location",
  stimulus: "./images/Tellus pohja small.png",
  stimulus_width: 400,
  stimulus_height: 400,
  stimulus_zoom: 11,
  preamble: "Where are you now?",
  required: true
};

timeline.push(test_location);
```

Figure 28. The parameters of the location plug-in and pushing it to the timeline.

4.1.4.2 Affect Grid Plug-In

The affect grid plug-in is done using the CSS grid layout module. More specifically, there is a main 3-by-3 grid, in which the center cell contains a nested 9-by-9 affect grid using html-buttons, as shown in Figure 29. This setup allows for a responsive layout for different devices. The main grid contains the affect grid labels in the relevant cells. The plug-in returns the response data in an object with x and y values, which are used to analyze how the participant feels.

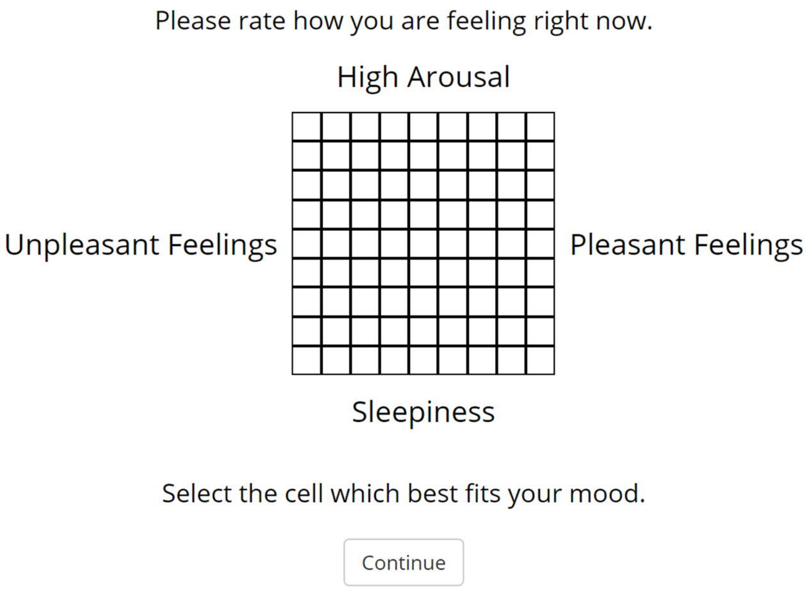


Figure 29. The affect grid question in the survey.

Each button in the affect grid has a maximum width and height of `3vw`, which is 3% of the viewport width. This allows the grid to be responsive for different screen sizes. The minimum size is set to be 20px using the `minmax()` -function, as shown in the Figure 30. This way, the buttons will be large enough to be useful and scale appropriately across various devices. The `repeat()` function allows to set the sizes for the nine grid rows and columns in a concise form.

```css
.grid-container {
  display: grid;
  grid-template-columns: auto auto auto;
  grid-template-rows: auto auto auto;
  grid-gap: 0px;
}

.grid-btn-container {
  display: grid;
  grid-template-columns: repeat(9, minmax(20px, 3vw));
  grid-template-rows: repeat(9, minmax(20px, 3vw));
  grid-column: 2;
  grid-row: 2;
  grid-gap: 0px;
}

.grid-item-btn {
  border: 1px solid black;
  width: 100%;
  height: 100%;
  background-color: white;
}

.grid-item-btn-active {
  background-color: black;
  border: 1px solid black;
  width: 100%;
  height: 100%;
  outline: none;
}
```

Figure 30. CSS styling of the grids and the buttons.

4.1.4.3 The Client-Side

When the client loads the survey website, the browser loads the index.html file as described in Figure 31. It contains the relevant files for the jsPsych, CSS styling, Leaflet plug-in, and a index.js file which runs the experiment.

```
<!DOCTYPE html>
<html lang="en">

<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta http-equiv="X-UA-Compatible" content="ie=edge">
    <title>MoodFoam</title>
    <script src="./jspsych-6.1/jspsych.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-html-button-
response.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-survey-multi-
choice.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-survey-multi-
select.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-survey-likert.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-affect-grid.js"></script>
    <script src="./jspsych-6.1/plugins/jspsych-location.js"></script>
    <link href="./jspsych-
6.1/css/jspsych.css" rel="stylesheet" type="text/css">
    </link>
    <link rel="stylesheet" type="text/css" href="style.css">
    </link>
    <script src="./index.js"></script>
    <link rel="stylesheet" href="https://unpkg.com/leaflet@1.6.0/dist/leaf
let.css"
        integrity="sha512-
xwE/Az9zrjBIphAcBb3F6JVqxf46+CDLwfLMHloNu6KEQCAWi6HcDUbeOfBIptF7tcCzusKFjFw2y
uvEpDL9wQ=="
        crossorigin="" />
    <script src="https://unpkg.com/leaflet@1.6.0/dist/leaflet.js"
        integrity="sha512-
gZwIG9x3wUXg2hdXF6+rVkLF/0Vi9U8D2Ntg4Ga5I5BZpVkVxlJWbSQtXPSiUTtC0TjtGOmxa1AJP
uV0CPthew=="
        crossorigin=""></script>
</head>
<body></body>
</html>
```

Figure 31. The client-side index.html file.

The public `index.js` file initializes the experiment timeline and sets the action when the experiment is finished. This is described in Figure 32. The experiment data can be retrieved with the `jsPsych.data.get().json()` command. When the experiment is finished, the `on_finish` callback calls the asynchronous `sendData()` function with the experiment data as the argument. The data is sent using the fetch-API that uses additional parameters to specify the POST method, header content type, and the content of the body. The fetch-API allows for an easy implementation of an asynchronous operation.

```
jsPsych.init({
  timeline: timeline,
  on_finish: () => sendData(jsPsych.data.get().json())
});

async function sendData(data) {
  await fetch("/", {
    method: "POST",
    headers: {
      "Content-Type": "application/json"
    },
    body: data
  })
    .then(response => {
      if (response.redirected) window.location.replace(response.url);
    })
    .catch(err => console.log("Error:", err));
}
```

Figure 32. The jsPsych initialization and data sending method in the client-side.

4.1.4.4 The Server-Side

The MoodFoam survey uses a simple Node.js server for the backend. It uses the Express middleware to handle the server routing. Express is instantialized using `express()` and then a cookie-parser is used to handle the use of cookies. The server is set to listen to a certain port and to serve a static public page. This is shown in Figure 33.

```
require("dotenv").config();
const db = require("./database.js");
const express = require("express");
var cookieParser = require("cookie-parser");

const port = process.env.PORT || 5500;
const cookieoptions = {
  expires: new Date(2020, 3, 9)
};

const app = express();
app.use(cookieParser());
app.listen(port, () => console.log(`Moodfoam app listening on port ${port}!`));
app.use(express.static("public"));
app.use(
  express.json({ limit: "1mb" })
);
```

Figure 33. The Node.js server initialization.

The Node.js server uses a separate database module, which is described in the Figure 34. The modular structure of the database allows each respondent to have an instance of the database connection object.

```
const options = {
  error: function(error, e) {
    if (e.cn) {
      // A connection-related error;
      console.log("CN:", e.cn);
      console.log("EVENT:", error.message);
    }
  }
};
const pgp = require("pg-promise")(options);
pgp.pg.defaults.ssl = true;
const cn = process.env.DATABASE_URL;
const db = pgp(cn);

module.exports = db;
```

Figure 34. The database module in the server, to create a connection for the client.

After the respondent finishes the survey and submits the response, the server receives the POST request and processes it as described in Figure 35.

```
app.post("/", (req, res) => {
  let cookieid = req.cookies.id;
  if (cookieid === undefined) {
    cookieid = getRandomNumber();
    res.cookie("id", cookieid, cookieoptions);
    console.log("Cookie created successfully", cookieid);
  } else {
    console.log("Cookie exists", cookieid);
  }
  db.none("INSERT INTO responses(response, timestamp, id) VALUES($1, $2, $3)", [
    { data: req.body },
    new Date(),
    cookieid
  ])
    .then(() => {
      console.log("DB insert success");
    })
    .catch(err => {
      console.log(err);
    });
  res.redirect(307, "end.html");
});
```

Figure 35. The POST method implementation in the server side.

The survey uses cookies to identify users to see how many times each user responds. The server checks if the client already has a cookie set. If they do not have it, a random number used for the cookie id value is generated with a function in Figure 36. The function creates a sufficiently long integer to ensure that the probability of two cookies having the same id is very low.

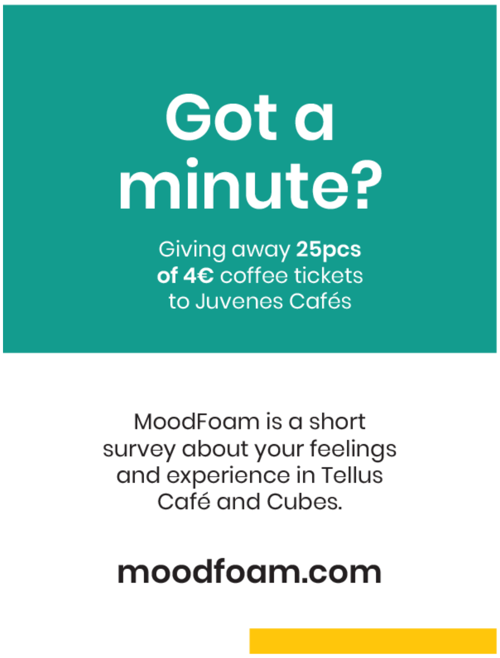
```
function getRandomNumber() {
  let randomNumber = Math.random().toString();
  randomNumber = randomNumber.substring(2, randomNumber.length);
  return randomNumber;
}
```

Figure 36. Random number generation for the cookie id.

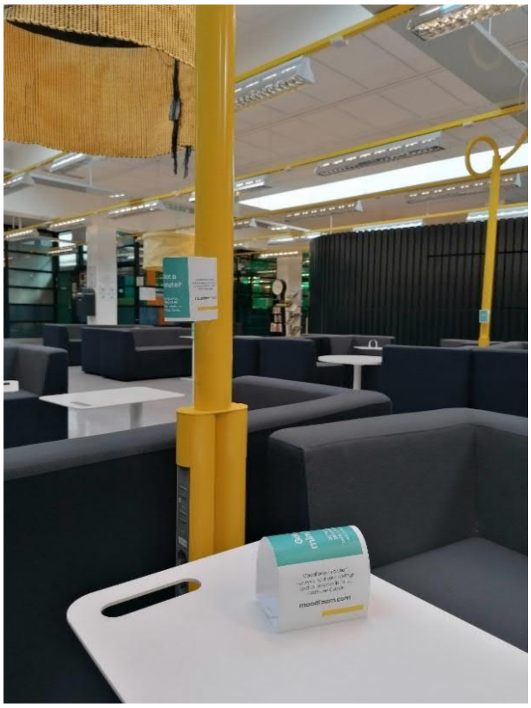
4.1.5 Deployment

The survey was available for two weeks, from February 24, 2020 (Monday) to March 8, 2020 (Sunday). The survey was advertised in Tellus during that period with advertisement, as shown in Figure 37a and b, which were designed to attract the attention of the users of the space. To incentivize to respond, Tellus provided 25 coffee tickets of 4 euros each for the raffle to the survey respondents.

To ensure an easy access to the survey, a short link, moodfoam.com, was provided. The survey was not advertised in the mailing lists or in the campus advertisement screens outside of Tellus, because it could have changed the natural pool of respondents.



(a) An A4 size poster advertisement for the survey.



(b) The two types of advertisement on the tables and power poles in Tellus.

Figure 37. Types of advertisement for the survey in Tellus.

4.2 The Sensor Data Collection

An API is used to collect the sensor data described in chapter 2.2. Interacting with the API is done using HTTP methods. For retrieving the data, a GET request is sent to the API URL with “from” and “to” fields which specify the range for the desired sensor data. The API was specified to have a maximum time range of 5 hours per request to keep the response size adequately small. This process is described in the sequence diagram in Figure 38.

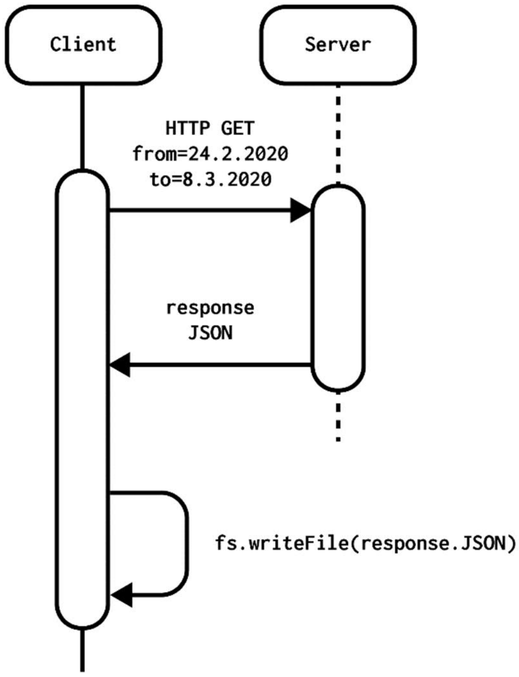


Figure 38. The sequence diagram for the sensor data API.

To retrieve the data from the whole time period of the survey, an algorithm was written in JavaScript to request all of the data, as shown in Figure 39. The API URL is redacted for privacy. The algorithm utilizes a JavaScript Moment library, which is a robust way to manipulate dates in JavaScript. The algorithm divides the time range from the start to the finish into chunks of 4 hours using the `moment.range()` function and a specific time format. Then it uses a fetch API to send a GET request for each of those chunks and saves them to a local file. This process produces multiple JSON files, which can then be combined into a single file. An algorithm to combine the JSON files is in Appendix 2.

```
const argv = require("minimist")(process.argv.slice(2), {
  default: {
    from: "27.01.2020_08:00:00",
    to: "03.02.2020_00:00:00"
  }
});

const Moment = require("moment");
const MomentRange = require("moment-range");
const moment = MomentRange.extendMoment(Moment);
const fs = require("fs");
const fetch = require("node-fetch");

const fetchDuration = 4; // hours

const day_start = moment(argv.from, "DD.MM.YYYY_HH:mm:ss");
const day_end = moment(argv.to, "DD.MM.YYYY_HH:mm:ss");
const day = moment.range(day_start, day_end);
const time_slots = Array.from(day.by("hours", { step: fetchDuration }));

for (let i = 0; i < time_slots.length - 1; i++) {
  fromTime = time_slots[i].format("DD.MM.YYYY HH:mm:ss");
  toTime = time_slots[i + 1].format("DD.MM.YYYY HH:mm:ss");

  const url = `http://URL_REDACTED/getdata/tellus?from=${fromTime}&to=${to
Time}`;
  sendRequest(url, i);
}

function sendRequest(url, index) {
  fetch(url, {
    method: "GET"
  })
    .then(response => { return response.json(); })
    .then(myJson => { saveData(myJson, index); });
}
```

Figure 39. An algorithm which gets the sensor data between two time periods.

The JSON data and its index are passed to the `saveData()` function, which saves it to a local file using the `fs` module, as shown in Figure 40.

```
function saveData(data, index) {
  fs.writeFile(
    `./output/sensordata-${index}.json`,
    JSON.stringify(data, null, 2),
    err => {
      if (err) {
        console.error(err);
        return;
      }
    }
  );
  console.log(`File with index ${index} has been created`);
}
```

Figure 40. The function which saves the sensor data to a local file.

5 DATA ANALYZATION

After the data gathering period was completed, the data was retrieved, analyzed, and plotted using statistical programming language R and its corresponding free IDE, R Studio. The data gathering process resulted in four data frames: sensor and survey data from both the café and the cubes. This allows for comparing the data from the café against the cubes. Also, it allows for comparing the survey data to the sensor data in each location. The following chapters describe how each data frame was created and how the data was further visualized.

5.1 The Survey Dataset

The total number of responses was 40. The first week resulted in 34 responses and the second week in 6 responses. This was due to the spring holiday which took place in the second week. This was known, but the effects of it were larger than anticipated. Also, the Café Tellus was closed on the February 24th, the 25th, and the 28th. Next, the data from each dataset was filtered into two clusters based on the location, as shown in Figure 41.

```
# Cube, lat=y, lon=x
lat_min_cube = 0.10835064214174696
lat_max_cube = 0.13820585084593853
lon_min_cube = -0.25405883789062506
lon_max_cube = -0.10746002197265626
df_cube <- subset(df, Lat > lat_min_cube &
                      Lat < lat_max_cube &
                      Lon > lon_min_cube &
                      Lon < lon_max_cube)
 # Cafe
lat_min_cafe = 0.14644176422908767
lat_max_cafe = 0.27855901119767423
lon_min_cafe = -0.2633285522460938
lon_max_cafe = -0.13252258300781253
df_cafe <- subset(df, Lat > lat_min_cafe &
                      Lat < lat_max_cafe &
                      Lon > lon_min_cafe &
                      Lon < lon_max_cafe)
```

Figure 41. Subsetting the survey dataset using the gps coordinates of the café and the cubes.

The survey dataset sizes the subsets from the café and cubes are shown in Table 4. All of the responses came from unique cookie ids.

Table 4. Survey dataset size after data filtering and subsetting.

	N, Café Tellus	N, Tellus Cubes
Week 1	12	12
Week 2	3	2
Total	15	14

5.2 The Sensor Dataset

The sensor dataset was collected using the algorithm presented in 4.2. It resulted in a 107 MB file with 547,785 rows of data with eight variables. Timewise, it corresponded the timespan from 24/2/2020 00:00:00 to 8/3/2020 23:59:59. The data was then subsetted using the location. Coordinates for each area were used to subset the dataset into their respective data frames, as shown in Figure 42.

```
# lat, lon (y, x)
lat_min_cafe = 65.05872151
lat_max_cafe = 65.05892835
lon_min_cafe = 25.46560954
lon_max_cafe = 25.46587508

lat_min_cube = 65.05864644
lat_max_cube = 65.05872151
lon_min_cube = 25.46560954
lon_max_cube = 25.46598841

cafe_sorted_data <- subset(sorted_data, lat > lat_min_cafe &
                                        lat < lat_max_cafe &
                                        lon > lon_min_cafe &
                                        lon < lon_max_cafe)

cube_sorted_data <- subset(sorted_data, lat > lat_min_cube &
                                        lat < lat_max_cube &
                                        lon > lon_min_cube &
                                        lon < lon_max_cube)
```

Figure 42. Subsetting the sensor dataset.

After subsetting, the sensor data resulted in two data frames. These are shown in Table 5.

Table 5. Sensor dataset sizes.

	Café Tellus	Tellus Cubes
N, Week 1	30,324	13,913
N, Week 2	30,323	13,915
N, Total	60,647	27,818
Sensors in area	46	21

5.3 Data Visualization

The datasets are plotted using the R ggplot library. The datasets from the survey and sensors are visualized in several different ways. The following subchapters describe how each type of data visualization is done using the ggplot library.

5.3.1 The Map

The image of the map is placed to the ggplot using the `draw_image()` function, as shown in Figure 43. The map is placed into the correct position, and then the datapoints are drawn with a filled circle to make them visible. The script result is shown in Figure 44.

```
ggplot(df, aes(x=Lon, y=Lat)) +
  draw_image(img, scale=0.4, x=-0.7, y=-0.3) +
  xlim(-0.4,0) +
  ylim(0, 0.4) +
  geom_point(size=4, shape=21, colour="black", fill="red", stroke=2) +
  coord_fixed() +
  ggtitle("Where are you now?") +
  theme_classic() +
  theme(
    plot.title = element_text(hjust=0.5, size=24),
    axis.text   = element_blank(),
    axis.title  = element_blank(),
    axis.ticks = element_blank(),
    panel.background = element_blank(),
    axis.line = element_blank(),
    panel.border = element_rect(colour = "black", fill=NA, size=0.4)
  )
```

Figure 43. The R script for creating the map.

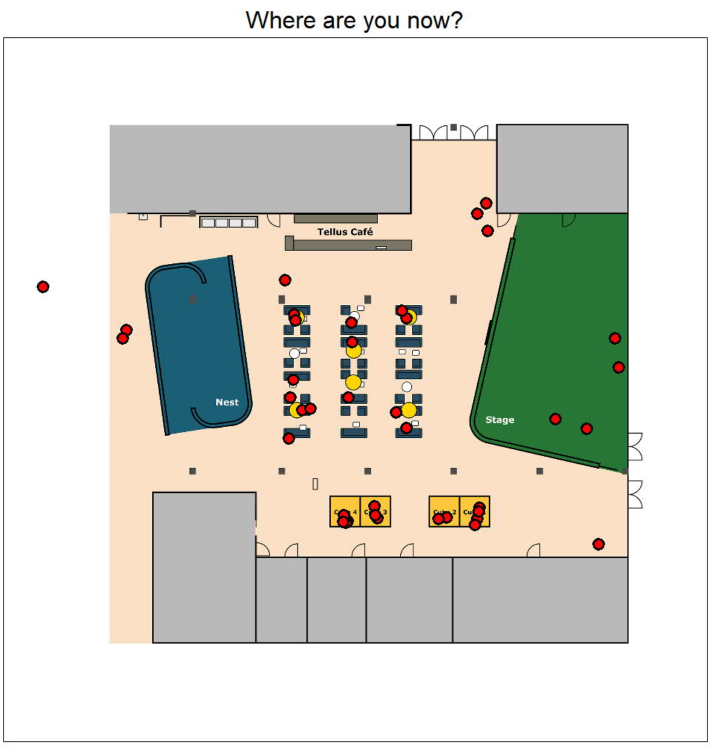


Figure 44. Responses from the Tellus. Each red dot represents a response.

5.3.2 The Bar Charts

The bar charts can be used to visualize the survey responses to compare the difference between the groups. This is shown in Figure 45 and Figure 46.

```
  ggplot(cafe_sorted_data, aes(timestamp, co2)) +
    geom_line() +
    scale_x_datetime(limits=lims, breaks=date_breaks("1 hour"), labels
= date_format("%H")) +
    geom_smooth() +
    coord_polar() +
    ggtitle("Tellus cafe co2-levels on 24.2.2020") +
    ylab("co2 (ppm)") +
    theme_minimal() +
    theme(
      axis.title.x = element_blank(),
      plot.title = element_text(hjust=0.5),
      axis.text.x = element_text(size = base * expand)
    )
```

Figure 45. Creating the bar charts.

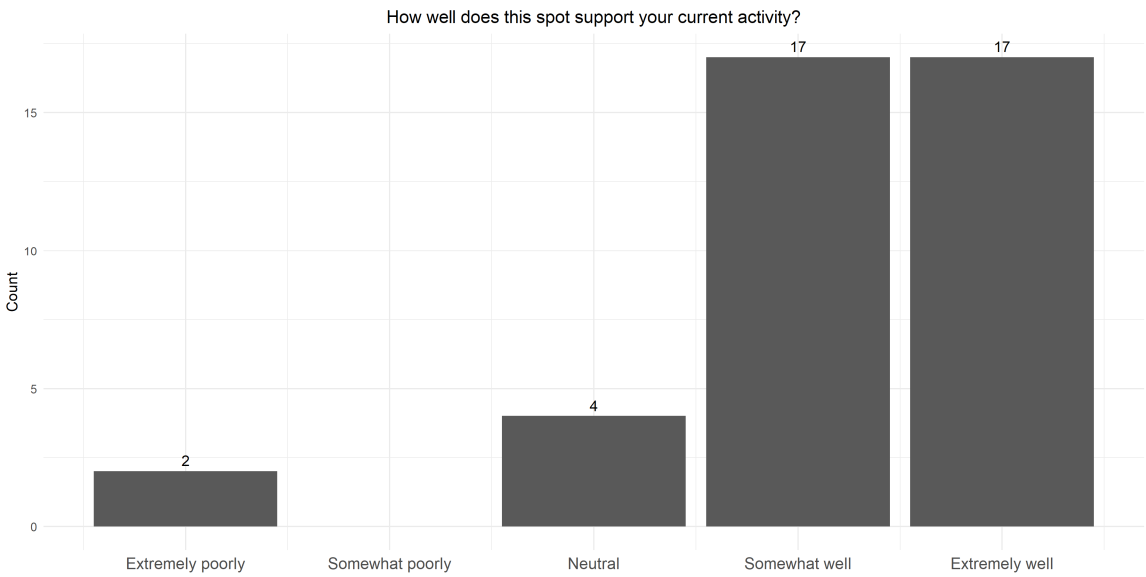


Figure 46. Bar chart of the suitability of the chosen spot across all responses.

5.3.3 Linear Time Series

The data can be plotted into a simple chart with time on the horizontal axis and a value on the vertical axis. It provides an easily understandable visualization of change over time. This is shown in Figure 47 and Figure 48.

```
ggplot(cafe_sorted_data, aes(timestamp, temperature)) +
  geom_line() +
  scale_x_datetime(limits=lims, breaks=date_breaks("1 hour"), labels
= date_format("%H")) +
  ggtitle("Tellus cafe temperature-levels on 24.2.2020") +
  geom_smooth() +
  ylab("Temperature (Celsius)") +
  theme_minimal() +
  ylim(17, 21) +
  theme(
    axis.title.x = element_blank(),
    plot.title = element_text(hjust=0.5),
    axis.text.x = element_text(size = base * expand)
  )
```

Figure 47. Linear time series visualization.

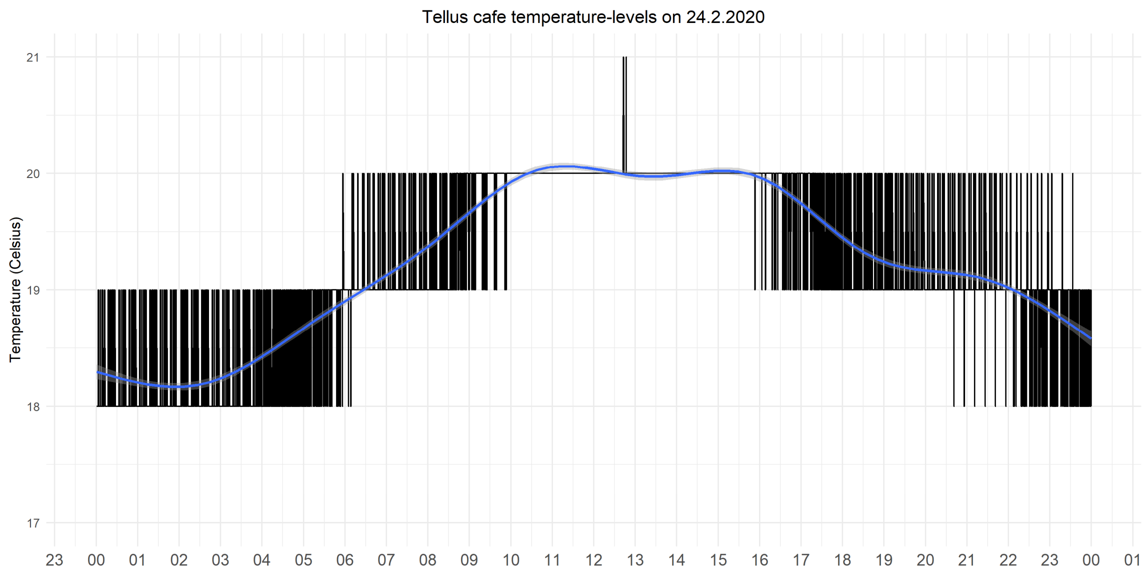


Figure 48. The linear time series visualization of the temperature levels in Café Tellus.

5.3.4 Cyclic Time Series

The time series data can also be arranged cyclically using polar coordinates. It allows to visualize events which have a cyclic form. A day, a week, and a month are all examples of cyclic time series. The cyclic visualization is shown in Figure 49 and Figure 50. As previously, a trendline is added with the `geom_smooth()` -item.

```
ggplot(cafe_sorted_data, aes(timestamp, co2)) +
  geom_line() +
  scale_x_datetime(limits=lims, breaks=date_breaks("1 hour"), labels
= date_format("%H")) +
  geom_smooth() +
  coord_polar() +
  ggtitle("Tellus cafe co2-levels on 24.2.2020") +
  ylab("co2 (ppm)") +
  theme_minimal() +
  theme(
    axis.title.x = element_blank(),
    plot.title = element_text(hjust=0.5),
    axis.text.x = element_text(size = base * expand)
  )
```

Figure 49. Creating the cyclic time series visualization.

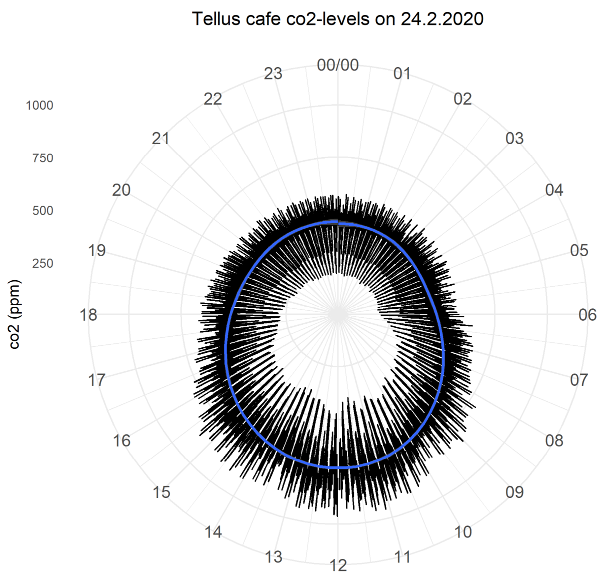


Figure 50. Cyclic time series data of the CO_2 levels in the Café area.

5.3.5 *The Affect Grid*

The affect grid is visualized using the `geom_2dbin` plot type. It divides the plot area into bins with specific dimensions, and the number of datapoints in each bin is counted. This is shown in Figure 51 and the resulting example in Figure 52. The color of the bin shows the number of datapoints.

```
ggplot(df, aes(x=x, y=y, fill=..count..)) +
  geom_bin2d(binwidth = c(0.999, 0.999)) +
  coord_fixed(xlim = c(0.5, 8.5), ylim = c(0.5, 8.5)) +
  scale_x_continuous(breaks = seq(0.5, 8.5, 1),
                     labels = seq(1, 9, 1),
                     name="Sleepiness",
                     sec.axis = sec_axis(~ . ,seq(0.5, 8.5, 1), labels =
seq(1, 9, 1), name = "Arousal")) +
  scale_y_continuous(breaks=seq(0.5, 8.5, 1),
                     labels = seq(1, 9, 1),
                     name="Unpleasantness",
                     sec.axis = sec_axis(~ . ,seq(0.5, 8.5, 1), labels =
seq(1, 9, 1), name = "Pleasantness")) +
  theme_classic() +
  theme(
    axis.text = element_blank(),
    axis.ticks = element_blank(),
    axis.title = element_text(size=24),
    legend.title = element_text(size=16),
    legend.text = element_text(size=12),
  ) +
  labs(fill = "Count") +
  scale_fill_viridis()
```

Figure 51. Visualizing the affect grid results.

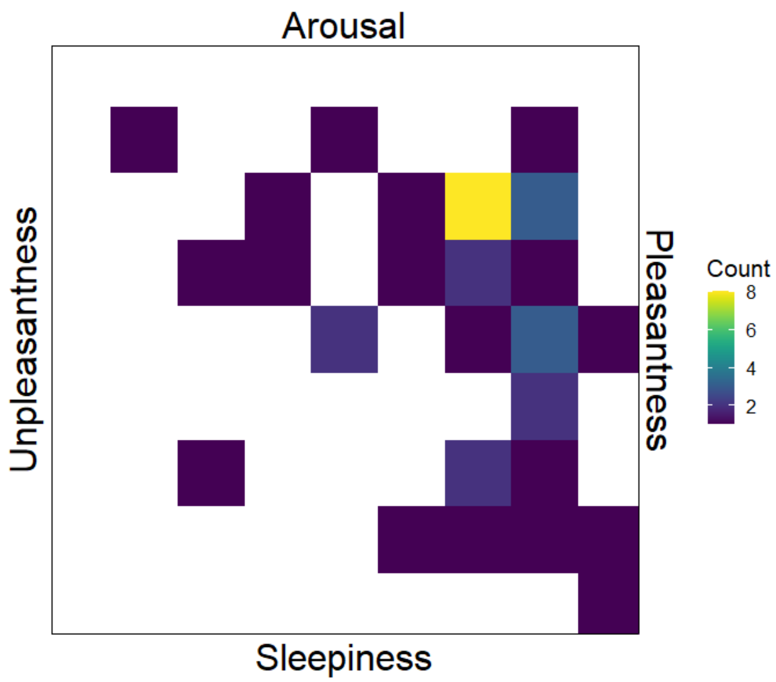


Figure 52. Affect grid visualization results using the dataset from the cubes and the café.

6 RESULTS

When it comes to theory, data gathering, and data processing, the previous chapters lead to the core of this thesis: how to combine these factors into a meaningful outcome? Furthermore, were the used tools—that is, the survey and the sensor data—suitable for this task? What kind of knowledge have the methodology and process brought into understanding of how humans experience spaces and, more specifically, multi-spaces?

The methodology developed in this thesis combined survey and sensor data from both Café Tellus and the cubes. These data can be analyzed in various ways, depending on the aspects relevant to the study. In this chapter, the two locations are compared using different variables.

6.1 The Responses

The MoodFoam survey was developed and deployed successfully, and subjective data from Café Tellus and cubes was gathered. Also, the sensor data collection successfully provided a large set of environmental data from the whole survey period. All the data was analyzed using R and visualized in various ways.

The survey responses are visualized in Figure 53, showing clearly that the spring break decreased the amount of responses quite significantly. Also, Café Tellus was closed on February 24, 25, and 28. This can also affect the amount of responses in the café, which was the larger space of the two.

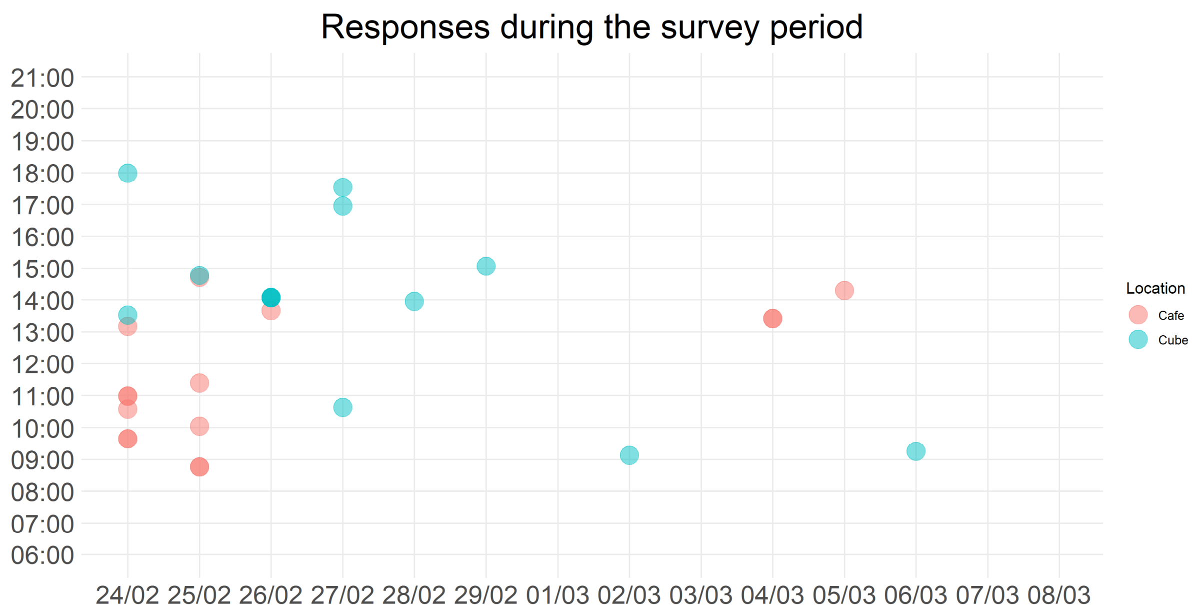


Figure 53. Responses from the survey period (N=29). It can be seen that more answers took place in the afternoon rather than in the morning.

Most of the responses came from students, and almost all of the users of the cubes were students as well, as shown in Figure 54.

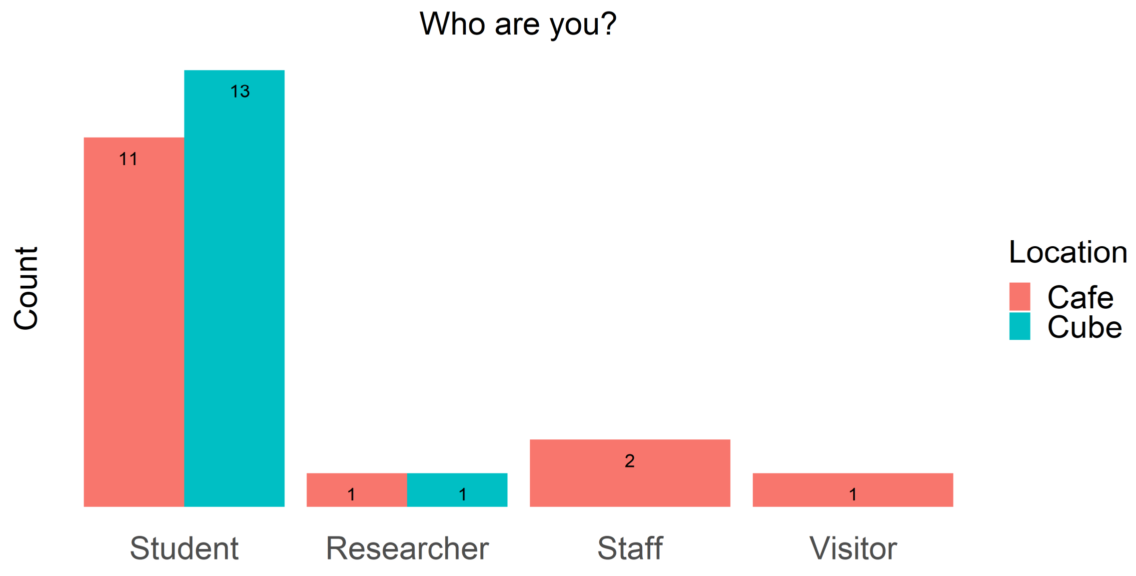


Figure 54. Roles of the participants in the café and the cubes.

The multi-space nature of the café and the cubes resulted in counting the ways people use those spaces, as shown in Figure 55. Most of the people using the cubes were working, either together or alone. The café was also used more as a space to avoid work or to eat and drink. However, the café afforded working together or alone for some people. Gathering information about the usage of the space gives interesting insight into the perceived affordances of these spaces, and Café Tellus is used for working more than expected.

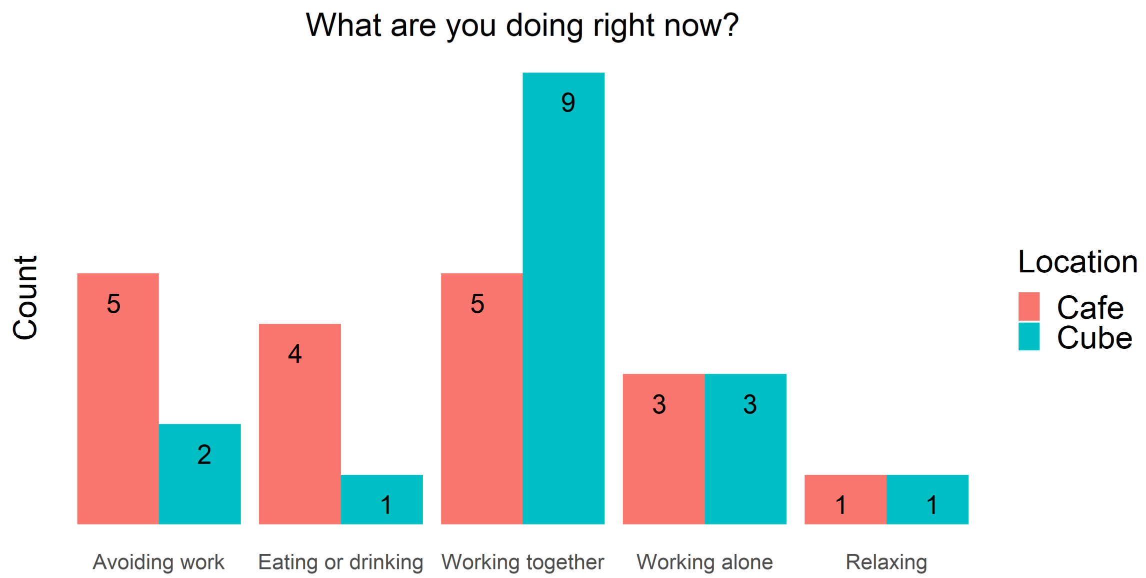


Figure 55. Activities in the café and the cubes.

Knowing the group size helps to understand the context in which the person is experiencing the space. The sizes of the groups is visualized in Figure 56, showing that the café was used mostly alone or in a group of two, whereas the cubes were used by groups of various sizes. Surprisingly, apart from one “5 or more” answer, the café was not used by larger groups of people.

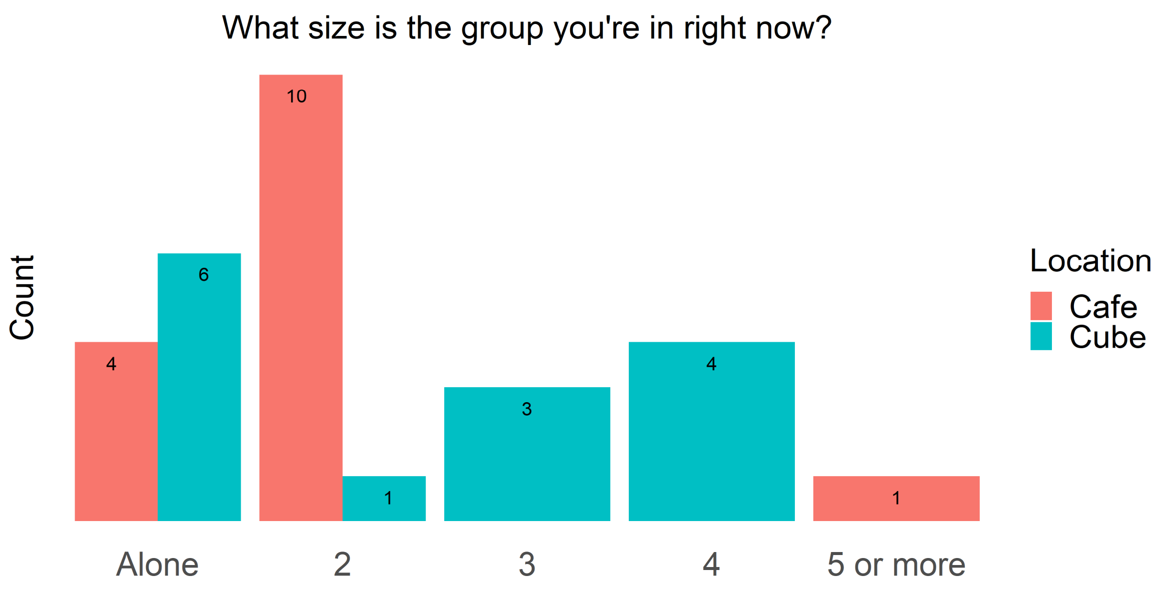


Figure 56. The size of the groups in the café and the cubes.

6.2 The Sensor Data

The sensor data can be compared between the different areas as well. In Figure 57, the café and the cubes are compared in terms of temperature, CO_2, relative humidity, light, and motion detection. The trendlines represent the average values from all of the sensors in their respective areas. The main differences in the light levels and motion detections can be explained by the cubes and their sensors being located away from the ceiling windows, and the cube area being smaller and away from the major paths. Otherwise the sensor readings align quite well.

The figure also shows how the presence of humans affects environmental factors, that is, the temperature and the CO_2. For example, the average temperature is two degrees higher on Monday, February 24 compared to Sunday, March 1. The relative humidity does not correlate as clearly as the temperature or the CO_2 levels do. The light levels are also affected by human presence, which is caused by the automated lights that turn on when the lamps detect movement. Based on this fact, the light levels can be used to assess human presence more accurately than the motion sensors, which take readings only every 15 minutes.

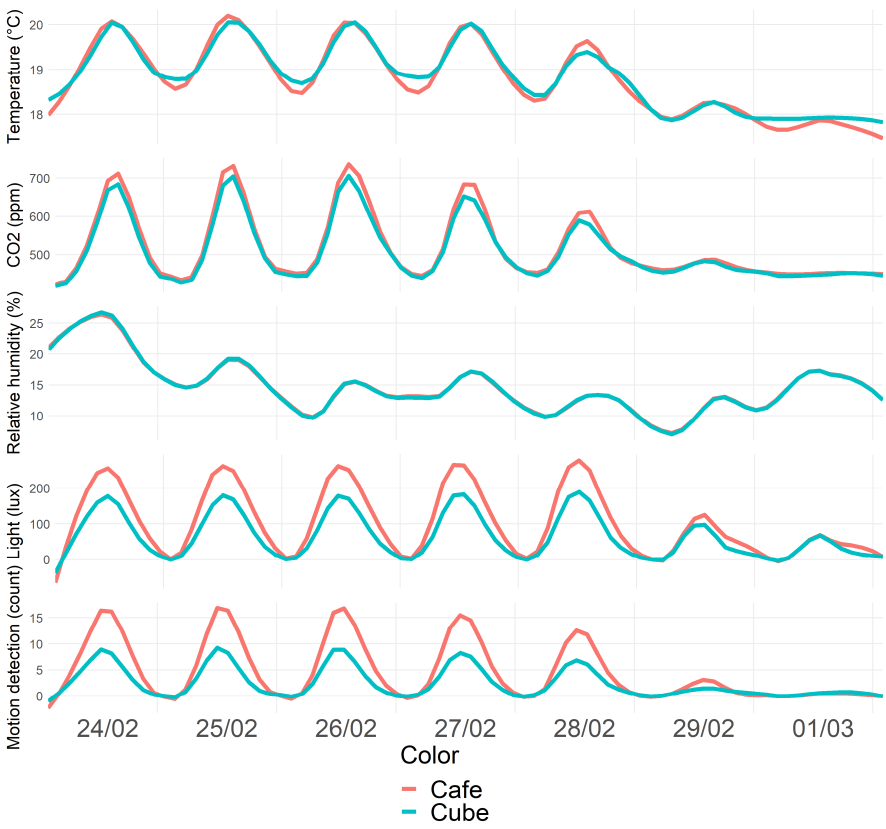


Figure 57. Average values of the sensor data in the café and the cubes during the first week.

6.3 The Spatial Experience

The methodology allows for gathering insights on how spaces are experienced. It is notable that the sample sizes of 14 and 15 in the cubes and the café respectively are not large enough to be statistically meaningful, and as such they have a low accuracy for making any definite conclusions.

The suitability of the respondents' spot is visualized in Figure 58. Overall, the spaces were seen quite suitable for the current activities. This supports the idea that spaces are chosen for certain activities.

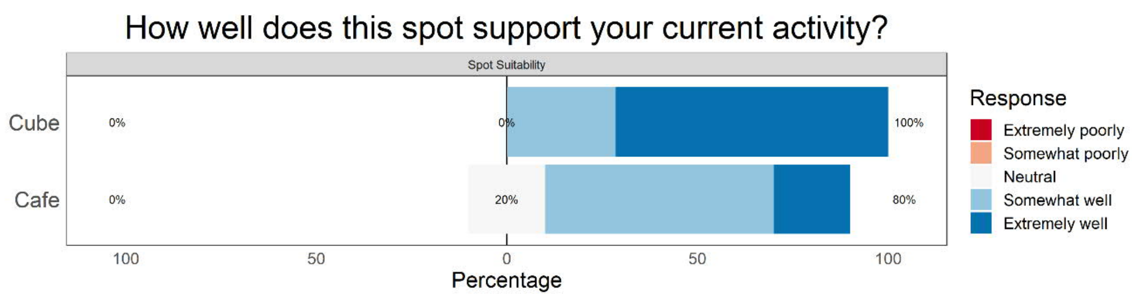


Figure 58. The suitability of the café and the cubes for the users' current activities.

The subjective experiences of spaces brought more differing opinions, as shown in Figure 59. Sound levels were seen more bothersome in the café than in the cubes. However, even with the relative acoustic insulation from the walls in the cubes, sound was bothering some people. This can be the result of the type of activities the cubes are used for: when working, sounds can be a larger disturbance. In terms of the theoretical vocabulary, the cubes are relatively porous to sounds.

As for temperature, the café resulted in more negative responses. This could be due to the fact that the isolated cubes have a more stable temperature, or perhaps the café has unsuitable air conditioning. Also, as the cubes are smaller, isolated units, the temperature might seem more suitable as the cubes heat up from body heat and electronic devices.

Smells were seen more as an issue in the cubes, which implies the cubes are not too porous for smells. The cubes have an air conditioning unit, but these results suggest its deodorizing aspects are not good enough. In the open space of the café, the responses do not show any distracting smells, which can maybe be explained by the pleasant smells of the café, such as coffee.

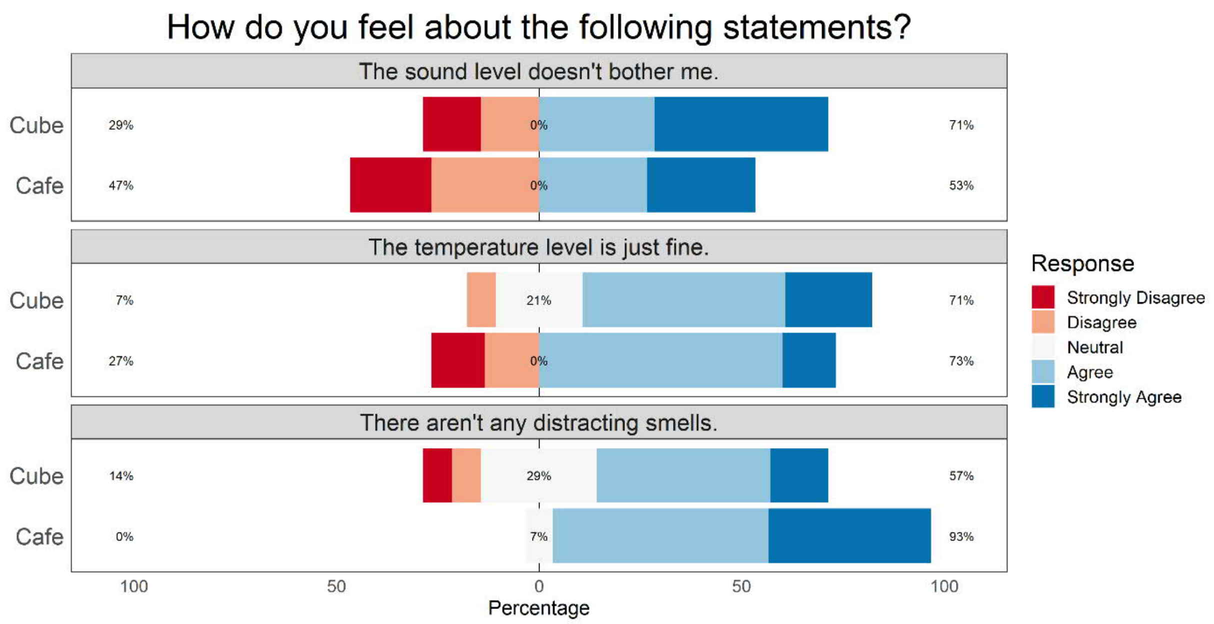


Figure 59. The experiences to the sound, temperature, and smells in the Café Tellus and the cubes.

In the theoretical framework of the atmospheric foam, the difference in the experience of the space supports the idea that atmospheres are local. The café and the cubes are in the same general area; however, the spaces are experienced differently. It can be due to the atmosphere of the space or the ways the space is used. The spaces can set certain expectations about their porosity and what kind of sensations each space affords. For example, the quiet relaxation space Nest in Tellus is dimmer, and the space implies the user can separate themselves atmospherically from the brighter areas surrounding it.

The reported moods were mostly mildly pleasant and mildly aroused, as shown in Figure 60. While keeping the sample sizes in mind, there were no significant differences between the café and the cubes. To make further deductions of the mood, it is necessary to understand the context where the mood was reported. This methodology allows for understanding the location and time of the mood, along with other factors of the data.

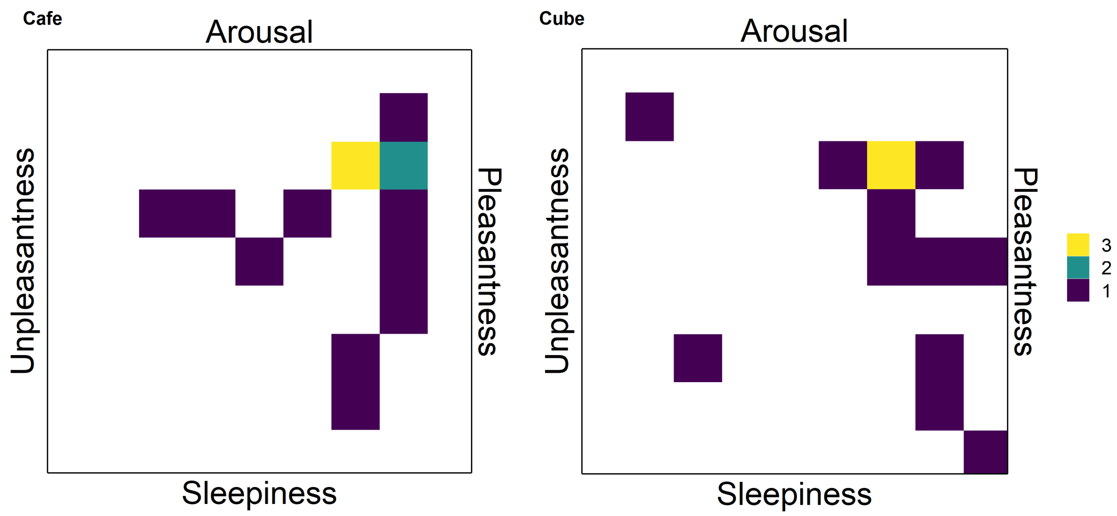


Figure 60. The affect grid results from the Café Tellus and the cubes.

Both the sensor and the survey data contain data about the temperature. It is now natural to combine these two to visualize them together, as shown in Figure 61 during the first week of the study. The MoodFoam methodology allows for reading the sensor data and the survey data and comparing these against each other. Depending on the available sensors, more factors can be introduced. For example, the survey could have had a question on the brightness levels, which was measured by the sensors, or there could have been sound level sensors to evaluate the subjective sound level experiences of the survey.

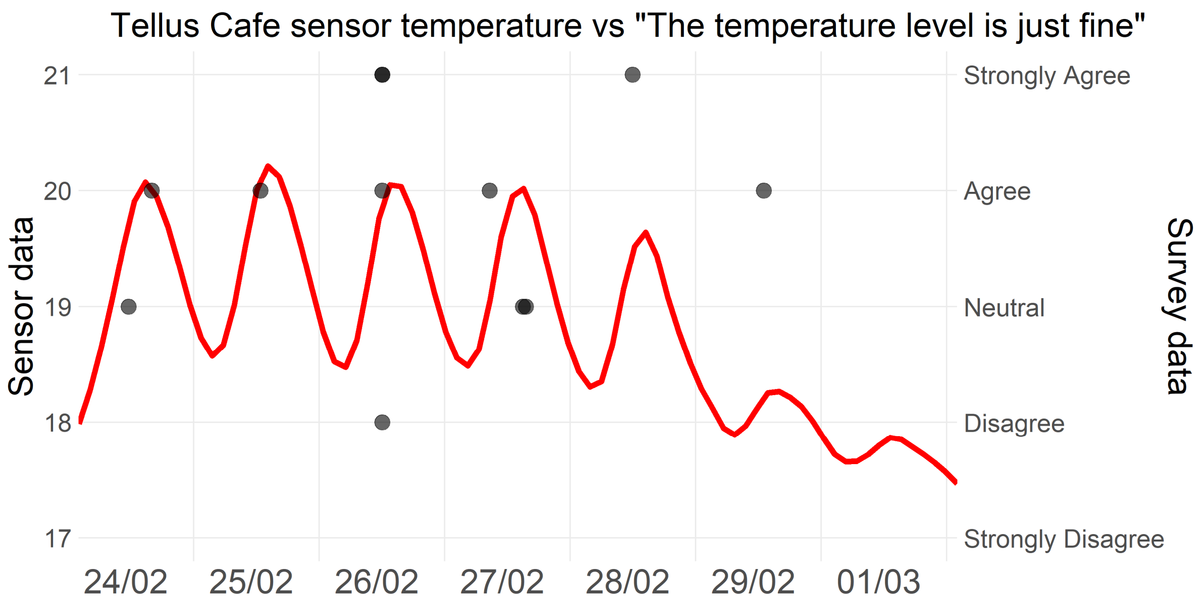


Figure 61. Combination of the sensor data and the survey data from the first week. The trendline is shown in red, and it represents the average temperature in the Café Tellus, showing approximately one degree increase in the temperature during the weekdays.

7 DISCUSSIONS

The presented methodology was successful in gathering data from the users of the space and the installed sensors. The results suggest the spaces can be understood through their smaller subdivisions. Based on the results, Café Tellus was experienced differently to the cubes, which implies that atmospheres are local. In this regard, these results are in line with the research presented by Andreani et al. which mapped people's spatial experience in the scale of urban environment and revealed the mood of these spaces [4]. The way people experience various spaces in cities varies intuitively, but as the results of this thesis suggest, this variation can occur even in a smaller, local scale, like in Tellus.

As the thesis provided a methodology from a new theoretical point of view and in the new context of the multi-spaces, related research is scarce to non-existent. The methodology allows for contextual understanding of different factors of a space. In Figure 62, the different variables of the results are connected with each other to show, for example, what variables could be analyzed against which. To extend the MoodFoam methodology further, aspects like extroversion/introversion, sociality, and visual distractions could be utilized in the survey to understand how these spaces work for different kinds of people or what distractions there are.

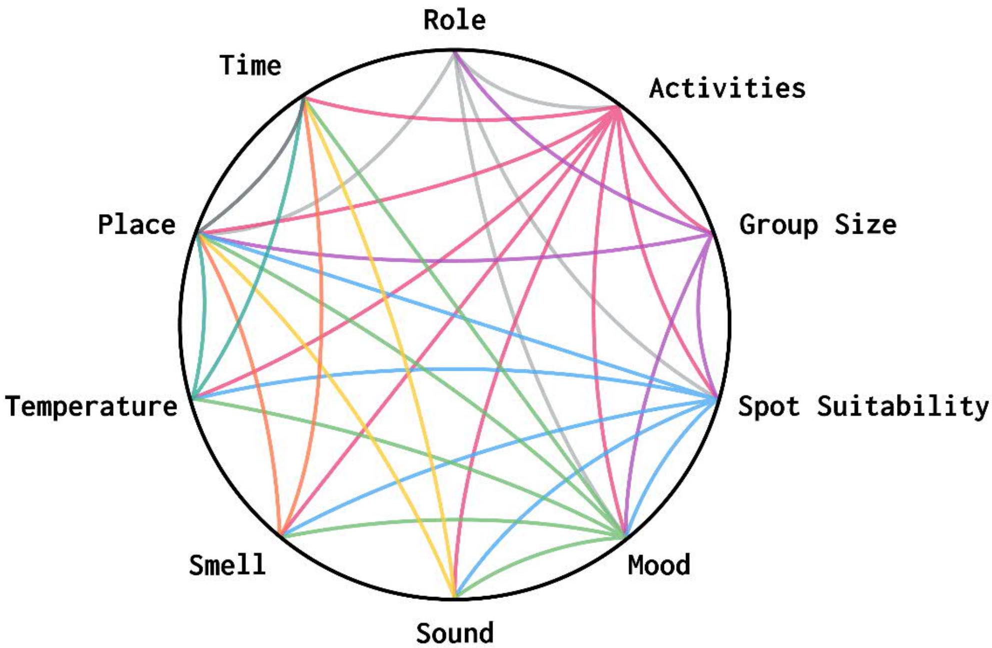


Figure 62. Variables of the MoodFoam data and the possibilities of visualization. For example, "smell" could be analyzed in a "place", at a specific "time", during certain "activities", its role in "spot suitability", or its relation to "mood".

7.1 The Limitations

The MoodFoam methodology can be improved in various ways due to certain limitations in the chosen approaches in this thesis. The data gathering period could have been chosen more carefully to ensure that there are enough participants in the space to answer the survey. Also, when the space is in abnormal state, the answers might reflect that. For example, the space can feel calmer and quieter with less people around; on the contrary, one can feel lonelier when no one else is around. These subjective experiences should be considered when analyzing the data.

The MoodFoam survey can be improved in few ways. First, the location was saved as a variable, which was not related to the real-world coordinates. Designing the location plug-in to save the location data as latitude and longitude, which represent the actual position of the person, would simplify the visualization process. Second, phrasing of the questions should have been done more carefully. For example, the subjective experience questions on smell, sound, and temperature levels were formed as the level of satisfaction, for example, "The temperature level is just fine". It results in answers which only describe the satisfaction towards a certain environmental factor, but it does not differentiate between "too cold" or "too warm". With a better phrasing of the questions, more information could be gathered, which in turn would allow adjustments to certain directions. Third, the precision of the location method could be further studied. The method allows for a precise positioning but is dependent on the user's abilities to orient themselves and place themselves on a map.

The sensor data collection was successful, but it could have been utilized more. Temperature was the only environmental factor present in the survey and the sensor datasets, and as such, the analysis of the sensor data is quite limited. Depending on the used sensors, the subjective questions can be formed to validate the sensor data. However, factors like CO_2 levels or relative humidity are difficult for humans to perceive directly, and their relevance to the atmospheric experience could be studied further.

The presented MoodFoam methodology can be developed and utilized further by testing it in various organizations with different contexts. The methodology can gather subjective data from a specific time and place, and by choosing the questions carefully, different aspects of the space can be researched.

7.2 The Achievement of the Aims

This thesis aimed at developing a methodology to gather data on spatial experience. To achieve this, a MoodFoam survey was developed using suitable tools for contextual data gathering. The survey utilized affect grid to gather user's mood, and the positioning was done with an infrastructure-free solution by using a simple marker on a map. The survey was able to be deployed and used throughout the data gathering period successfully. The sensor data was also able to be gathered through the server API with an algorithm, and then processed into a local file. The gathered data was then visualized through various means, highlighting different aspects of spatial experience.

To support the analyzation of the data, a new theoretical perspective of foams was utilized. It allowed for understanding the spaces as smaller subdivisions, each with their own atmosphere. The results suggest that the atmospheres are local and that the spatial experience can vary even in close-by spaces. Furthermore, the results support the idea that spaces can be understood through their porosity. The results also show how the multi-spaces of Tellus afford various kinds of activities. In light of these theoretical perspectives, and the data gathering method, the developed methodology achieved the aims of this thesis and brought further understanding in the field of spatial experience research.

7.3 The Significance of the Results

The results of this thesis lay a foundation on which further research on spatial experience can be built upon. The MoodFoam methodology serves as a practical application of Sloterdijk's foam theory and allows for understanding spaces through their interaction. The objective data from environmental sensors brought a backdrop against which subjective data could be analyzed for a more holistic image of the spatial experience. The thesis elucidates the usage of university's multi-spaces, which are gaining popularity and in need of further research to ensure suitable usage for all kinds of users and activities.

7.4 Further Work

The developed methodology in this thesis allows for further utilization in various aspects. Firstly, the presented infrastructure-free solution to gather positional data could be studied further, to test how precise humans are at locating themselves on a map. Hypothetically these are affected by the person's familiarity with the space and the presentational qualities of the map. Person's own abilities might be a factor as well, due to their own dexterity or the used device.

Secondly, the visualization of the results could be done automatically by developing an application to visualize based on the chosen factors. In an interactive map the user could select a certain area where to choose the results or from a certain time. The automatically generated visualization of the results would simplify the process of understanding the space by, for example, allowing the operators of the space to make improvements, if necessary. Development of such application was outside of the scope of this thesis, but this thesis, however, laid the groundwork for such an application to be developed.

Thirdly, using the existing MoodFoam methodology, other spaces could be studied to form a better understanding of the space and the methodology. Further work could aim towards a higher sample size for the survey, to minimize the effect of person-to-person variance. The methodology could also be combined with interviews to enable subjective descriptions elucidate certain factors of the space, which cannot be attained through the presented survey or sensor data.

8 CONCLUSIONS

Evaluating spatial experience and atmospheres is a multi-faceted subject which requires utilizing various methods from different fields. The aim of this thesis was to develop a methodology for gathering data from a multi-space area Tellus in the University of Oulu, and to visualize the data in order to understand how the space is experienced. The research began with a literature review from the relevant fields to understand the way spaces and atmospheres are understood in fields like architecture, engineering, philosophy, and psychology. This process gave the thesis its theoretical foundation by utilizing Sloterdijk's foam theory and the concept of porosity to highlight the interactionist nature of spatial experience. By focusing on the bodily experience of the senses and sensations, the spatial experience can be understood in a more holistic manner.

Tellus contains 330 environmental sensors which can measure CO_2 , temperature, relative humidity, light, and motion. Utilizing these sensors helped to form a more robust backdrop, against which the human experience is analyzed. Also, the sensor data could be used to gain information on how human presence affects the environmental factors. The sensors can be then located in Tellus using their GPS coordinates, and data frames from Café Tellus and the cubes could be then created.

To gather the subjective data from the users of Tellus, a MoodFoam web application was developed. It was built using a Node.js server and behavioral experiment library jsPsych, and it was hosted on the Heroku cloud application platform. Custom plug-ins for indoor positioning and affect grid were developed to gather location and mood data respectively. The MoodFoam survey was hosted online, and the link was advertised in the Café Tellus and the cubes.

The data gathering period happened over the course of two weeks. There were no technical issues with the MoodFoam survey. Spring break took place on the latter week, which affected the number of responses, but the methodology performance was still able to be evaluated. The survey resulted in 15 and 14 responses in Café Tellus and the cubes respectively. The sensor data was able to be gathered from the panoulu servers using an API and an algorithm which sends HTTP POST requests from the correct time period.

The survey and sensor data was analyzed using statistical programming language R, which resulted in various types of visualizations presenting the different aspects of spatial experience. The data frames from Café Tellus and the cubes were compared with several variables, such as group size, current activities, spot suitability, mood, and experience to subjective sensations like smell, sound, and temperature. In further work, these variables can be utilized to gather information on specific aspects of interest about the space or its users.

In conclusion, this thesis resulted in a methodology, which can be used to gather and analyze spatial experience data. The results suggest that the spaces in Tellus have their own local atmospheres and that they are suitable for different needs. The thesis provides the tools and further suggestions how the understanding of spaces can be broadened. The multi-disciplinary approach aimed to bridge the gap between the theoretical and practical understanding of the spatial experience.

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10 APPENDICES

Appendix 1 Elsys ERS CO_2 datasheet

Datasheet
Publish Date: 20.08.2019

ELSYS.se
LoRaWAN Wireless Sensor

ERS CO2

Description

ERS CO_2 is a sensor for measuring the indoor environment. It is enclosed in a room sensor box and is designed to be wall mounted. ERS CO_2 is completely wireless and powered by two 3.6V AA lithium batteries. Inside you will find internal sensors for measuring indoor CO_2 levels, temperature, humidity, light, and motion.

Applications

- Indoor environment measuring
- Smart buildings
- Workplace management
- Room occupancy

Product features

- LoRaWAN Certified CM
- CO_2 sensor
- Temperature sensor
- Humidity sensor
- Light sensor
- Motion detection sensor (PIR)
- NFC for configuration
- Configuration over the air

Device Specifications

Mechanical specifications	
Weight	80 g excluding batteries / 120 g including batteries
Dimensions	86 x 86 x 28 mm
Enclosure	Plastic, PC/ABS

Operating conditions	
Temperature	0 to 40 °C
Humidity	0 to 85% RH (non-condensing)

Device Power Supply	
Battery Type	2 x 3.6V AA Lithium Batteries
Expected Battery Life	<10 years (Depending on configurations and environment)

Device Logging Function	
Sampling Interval	Configurable via NFC and downlink configuration
Data Upload Interval	Configurable via NFC and downlink configuration

Elektroniksystem i Umeå AB Industrivägen 12, 90130 Umeå, Sweden
E-mail: support@elsys.se | Web: www.elsys.se

Radio / Wireless	
Wireless Technology	LoRaWAN® 1.0.3
Wireless Security	LoRaWAN® End-to-End encryption (AES-CTR), Data Integrity Protection (AES-CMAC)
LoRaWAN Device Type	Class A/C (configurable) End-device
Supported LoRaWAN® features	OTAA, ABP, ADR, Adaptive Channel Setup
Supportet LoRaWAN® regions	US902 – 928, EU863 – 870, AS923, AU915 – 928, KR920 – 923, RU864, IN865
Link Budget	137 dB (SF7) to 151 dB (SF12)
RF Transmit Power	14 dB / 20 dB (Region specific)

Data types			
Type value	*Type*	*Data size*	*Comment*
0x01	Temperature	2	-3276.5 °C → 3276.5 °C (Value of: 100 → 10.0 °C)
0x02	Humidity	1	0 – 100 %
0x04	Light	2	0 – 65535 Lux
0x05	Motion (PIR)	1	0 – 255 (Number of motion counts)
0x06	CO_2	2	0 – 10000 ppm
0x07	VDD (Battery voltage)	2	0 – 65535 mV
0x3D	Debug information	4	Data depends on debug information
0x3E	Sensor settings	n	Sensor setting sent to server at startup (first package). Sent on Port+1.

Sensors

Temperature

Resolution: 0.1 °C

Accuracy: ±0.2 °C (See figure 1)

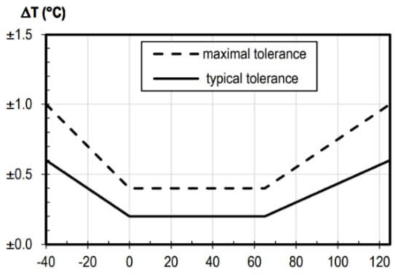


Figure 1

Humidity

Resolution: 0.1 % RH

Accuracy at 25 °C: ± 2 % RH (See figure 2)

Accuracy of humidity over temperature: See figure 3

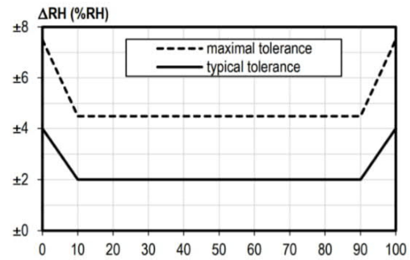


Figure 2

Light

Range: 4 – 2000 LUX

Resolution: 1 LUX

Accuracy: ± 10 LUX

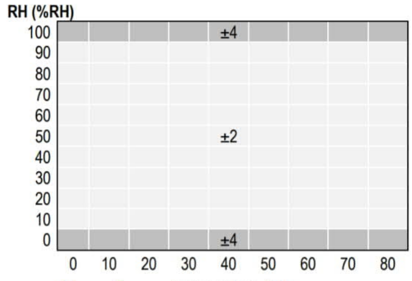
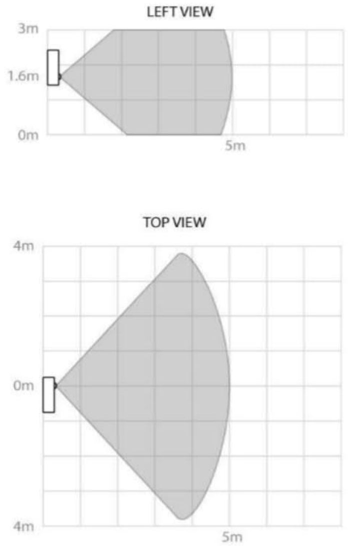


Figure 3

Motion (PIR)



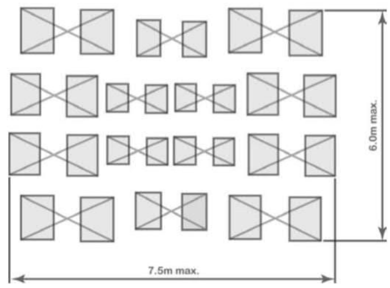


Figure 4 - Detection pattern

Note:
There is a blanking time of 30 seconds of the PIR triggering after each PIR trig and after each transmission. This is to reduce the risk of self-triggering from internal events that could disturb the high sensitivity PIR circuits.

CO_2

Range: 0 – 10000 ppm

Accuracy: ± 50 ppm / ± 3% of reading

Accuracy is met at 10 – 40°C, 0 – 60%RH, after minimum three (3) performed Automatic Baseline. Corrections, preferably spanning eight (8) days in-between, or a successful zero-calibration

Noise: 14 ppm @ 400 ppm / 25 ppm @ 1000 ppm

Note:
The CO2 sensor has an internal automatic calibration routine. This routine calibrates the sensor to set 400 ppm to the lowest value that has been read in the last period of approximately 8 days. This means that in an 8 day period, the sensor must be exposed to fresh (well ventilated) air at least once for the calibration to work. The sensor can also be manually calibrated.

Appendix 2 An algorithm to combine the JSON-files into a single one

```
const path = require("path");
const fs = require("fs");
var mergeJSON = require("merge-json");

let combinedJSON = [];

const dataPath = "output";
const directoryPath = path.join(__dirname, dataPath);

fs.readdir(directoryPath, function(err, files) {
  if (err) {
    return console.log("Unable to scan directory: " + err);
  }

  files.forEach(function(file) {
    const filePath = path.join(directoryPath, file);
    let data = fs.readFileSync(filePath).toString();
    let sensordata = JSON.parse(data);
    combinedJSON = mergeJSON.merge(combinedJSON, sensordata);
  });
  saveData(combinedJSON);
});

function saveData(data) {
  fs.writeFile(
    `./sensordata_combined.json`,
    JSON.stringify(data, null, 2),
    err => {
      if (err) {
        console.error(err);
        return;
      }
    }
  );
}
```